325 AMAZING IMAGES & CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

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SCIEN… …TRANSPORT HISTORY SPACE

INSIDE

RACHEL RILEY

THE TV BRAINBOX ON HER MUST-HAVE TECH

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- VERTICAL TAKEOFFS
- SELF-REPAIRING TECH
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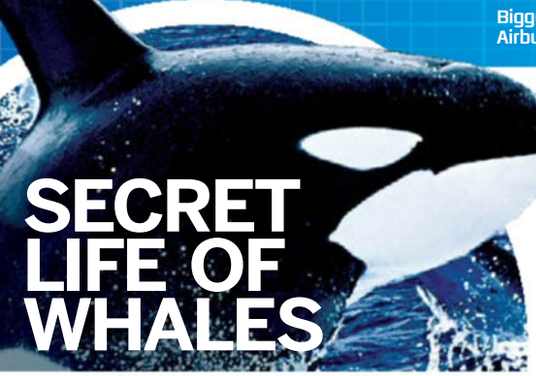
APPLE PAY EXPLAINED

Touch payments that will revolutionise shopping



SECRET LIFE OF WHALES

HOW WE SEE

Discover the secrets of our most dominant sense

HISTORY OF THE UNIVERSE

From the Big Bang to life on Earth and beyond

PHYSICS OF KITES

The amazing science behind staying airborne

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+LEARN ABOUT ■ ANCIENT ROME ■ ASTRONAUT SUITS ■ BONE FRACTURES ■ HIBERNATION

Xduro AMT pro 27.5

27.5", All Mountain, 150mm travel, 4-Link System • Bosch Performance 36 Volt, 250 Watt Motor, 60Nm Torque
Lithium Ion 400Wh Battery, max range 175km • Bosch Intuvia Display • Sprocket Equalizing System • Gravity Casting Interface • Skid Plate Motor Protection
Fox 34 Talas CTD Adjust FIT 120-150mm / Fox CTD Kashima • Sram X01 11-speed • Avid X.0 Trail Hydraulic Disc Brakes • Crank Brothers Iodine 3 Wheelset • 21.1kg

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ISSUE 66

WELCOME

The magazine that feeds minds!

Page 26
Whales are fascinating and mysterious animals – we try to unveil their secret lives

Some airline passengers will be content so long as their neighbour doesn't hog the armrest. Others, like myself, will be begging and bartering for a window seat and if you search for the term on Twitter, you'll see why. You can't beat the views from 12,200 metres (40,000 feet) in the air, but the porthole is so small that only one person can enjoy them. That's all set to change in the jets of the future, however.

In windowless planes, screens will line the cabin and project images of the outside world. This tech would also help to reduce the aircraft's weight and lower fuel costs. That's not the only way designers are looking to revolutionise the way we travel, either. Turn to page 14 to find out more.

Also in this issue, we explore the history of the universe (page 72), bask in the brilliance of Ancient Rome (page 36) and peer through the eyes of animals to find out how they see the world (page 46). It's set to be a pretty exciting journey, and what's more; there's absolutely no chance of being jostled by a flight attendant's drinks trolley.

Jodie

Jodie Tyley
Deputy Editor

Meet the team...

Andy
Art Editor
If it weren't for the Ancient Romans, we wouldn't have central heating or roads! Turn to page 36 for more.

Erlingur
Production Editor
Reading about orcas in our whales feature on page 26 made me realise they really are the *Mad Max* gangs of the oceans.

Jamie
Staff Writer
The future of air travel looks incredibly exciting, with the opposite side of the world soon to be just 90 minutes away.

Jackie
Research Editor
The science behind how we see is fascinating. Learn about how your eyes and brain create images on page 46.

Hannah
Assistant Designer
Have you ever wondered how long it would take you to walk around the Earth or to the Moon? Turn to page 78 to find out.

Jo
Senior Staff Writer
As well as making us hyper, additives also make our food much more appetising. Find out how on page 56.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

How do broken bones heal themselves? **Page 52**

Why do some animals hibernate in winter? **Page 35**

How does keyless entry control our vehicles? **Page 24**

How does Wimbledon's roof keep rain at bay? **Page 64**

How long does it take to drive to Neptune? **Page 78**

What did the Romans really do for us? **Page 36**

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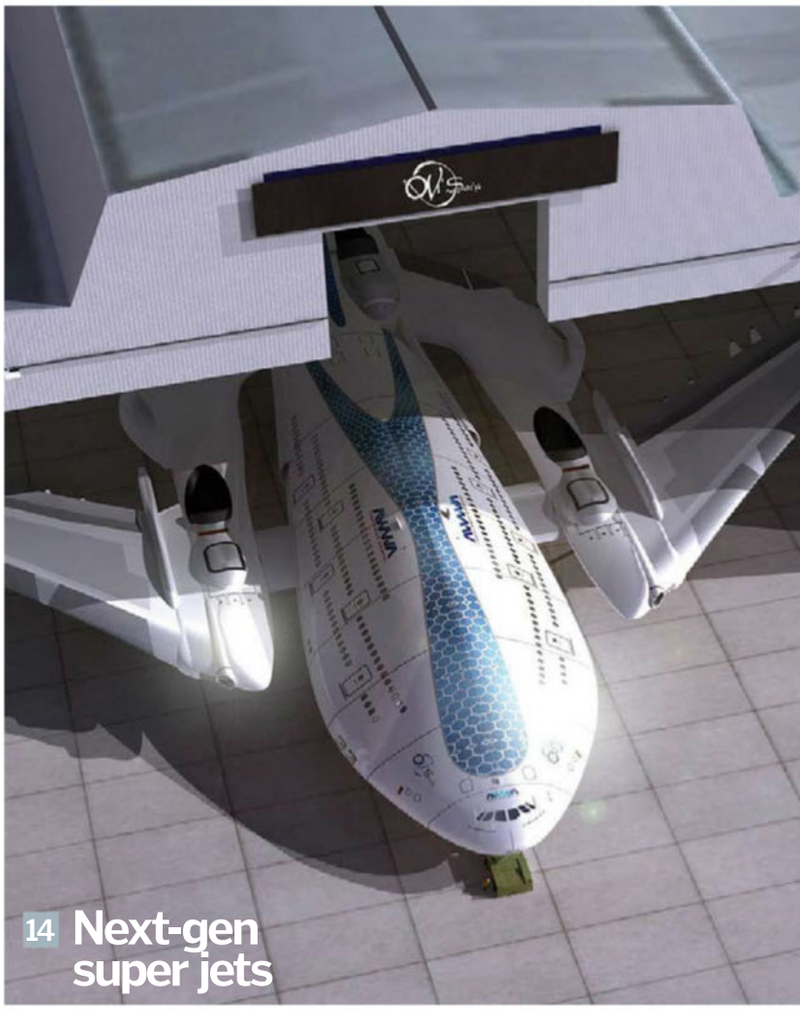
Discover the amazing technology powering the planes of tomorrow



Meet the experts...

Laura Mears
Science of vision
This month, Laura revealed the secrets of one of the most complex constructs in nature – the eye. You'll also discover how animals see the world. We don't fancy having a rat's eyesight...

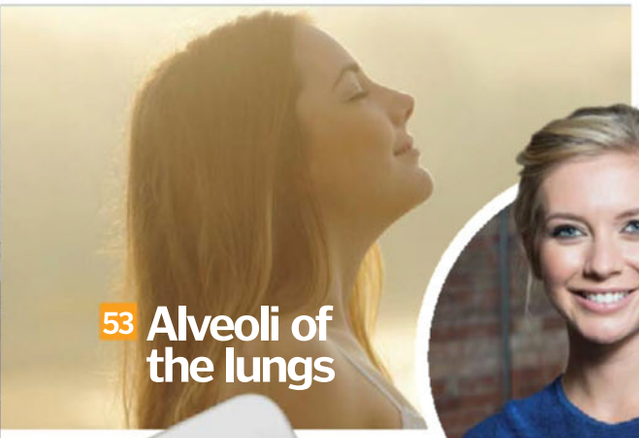
Hayley Paterek
Hibernation
As winter draws in, some animals are getting prepared to bed down and hibernate. Hayley tells us all about this strange process, as well as explaining how SAD lamps and eye drops work.

Lee Sibley
Supercar launch control
As editor of **Total 911** magazine, Lee gets to try out the latest and coolest vehicles. This month, he gets behind the wheel of a 911 Turbo to reveal how supercar launch control works.

Jack Griffiths
Ancient Rome
Jack indulges his love of history in this fascinating feature about what the Romans did for us. You can enjoy more of Jack's history articles over on our sister title **History of War**.

Gemma Lavender
History of the universe
Space expert Gemma briefs us on the history of the universe. It's no small feat either, as the Big Bang was over 13 billion years ago! Turn to page 72 for more.

Could it be possible to build a lift from Earth into outer space? Find out on pg 13



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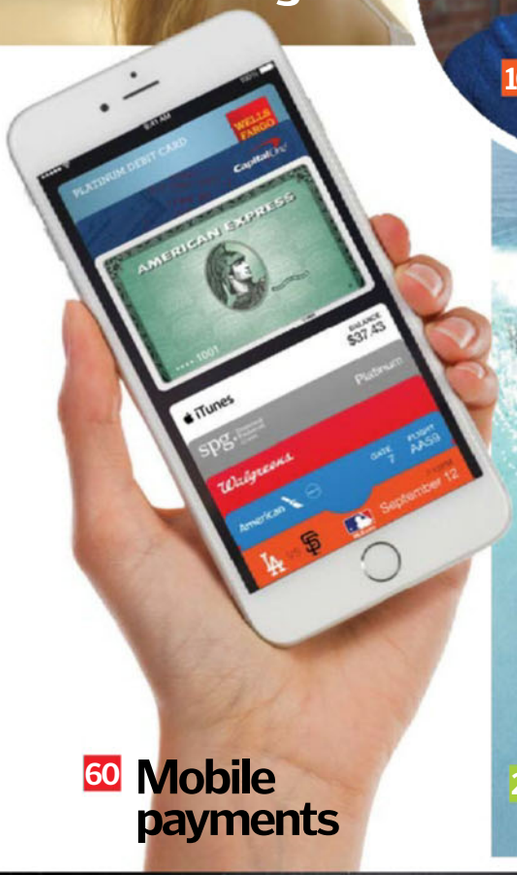

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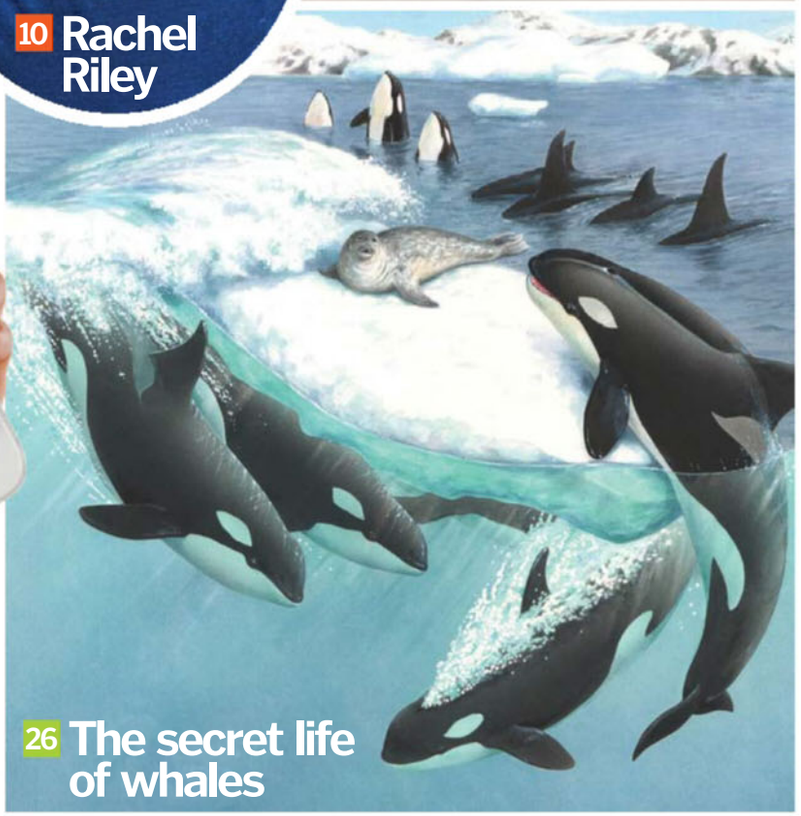

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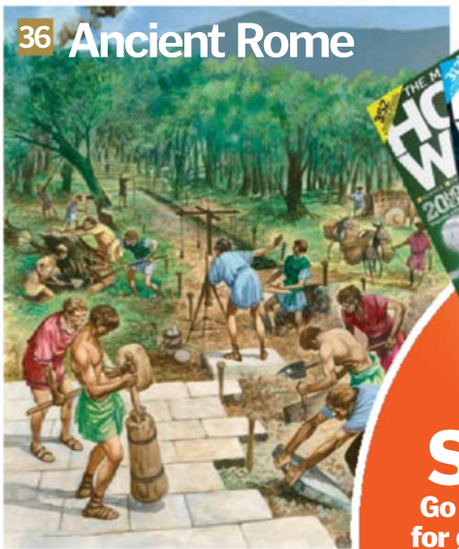

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REGULARS

08

A drone's eye view

Stunning pictures from across Europe, captured by a drone-copter

Providing a whole new perspective on Europe, photographer Amos Chapple captured aerial images using a camera mounted on a quadcopter drone. Pictures were shot all over the continent, from Spain in the west to Turkey in the east. This particular image shows the Spanish city of Barcelona from an angle you wouldn't normally see.

Autonomous drones or unmanned aerial vehicles (UAV) have become immensely popular in recent years, making life a lot easier for military reconnaissance and combat missions, as well as being a top-notch gadget for a civilian. With new technology allowing us to connect a drone to our smartphones via Wi-Fi, panoramic pictures like these could soon be taken from your very own drone.

ABOVE The drone used was a quadcopter with a camera attached

BELOW These new solar-energy collectors take inspiration from nature in their design

The future of solar power

How huge sunflowers could be the best form of renewable energy

Ten-metre (33-foot)-tall sunflowers could well be the future of human energy production. The towering metal structures can concentrate the Sun's radiation by 2,000 times and each one can generate enough energy to power several average homes. Created by Swiss-based Airlight Energy, the dish is made from patented fibre-based concrete, which has the same properties as aluminium, but at a fifth of the cost. It uses water-cooled photovoltaic chips which are ten times more effective than natural cooling. Installation is due to begin in late-2016 and will aim to service communities in remote areas.

AMAZING VIDEO!

Renewable energy sunflowers

www.howitworksdaily.com

SCAN THE QR CODE FOR A QUICK LINK

ABOVE The space-bound 3D printer being tested in microgravity

3D printing in space

Long-haul space missions get a 3D boost

The International Space Station (ISS) received its first 3D printer on 23 September 2014. Successful testing by NASA proved the machine could operate in microgravity, meaning that equipment can be manufactured on board. A 3D printer works by building layer upon layer of heated plastic, metal and other materials to create three-dimensional objects. This could well be a great technological leap for mankind, as this will signal the first time that an on-demand machine shop will be available in space. If the printer can produce a variety of products, this will be the first step to self-sufficient long-haul space missions and a manufacturing base in space.

Electric lava

A bolt from the blue strikes a Japanese volcano as it's erupting

This may look like a still from the next Hollywood survival blockbuster but this in fact a real volcano being struck by lightning as it erupts. Sakurajima is an active volcano on the island of Kyushu on the southern tip of Japan. It has been a hit with volcano-chasing photographers and this recent eruption isn't the first time that both phenomena have occurred at the same point. The amazing spectacle is sometimes known as a dirty thunderstorm and is caused by dust and rock particles colliding and producing static charges in the volcano's ash cloud.

ABOVE The ultimate light show taking place at Sakurajima in Japan

Rachel Riley

Countdown's queen of numbers reveals her must-have tech

Of all the school subjects, mathematics probably gets the least amount of love. TV's Rachel Riley is hoping to change that, though. Best known as the numbers expert on long-running British quiz show *Countdown*, the 28-year-old makes the subject look effortless and cool. In the show, contestants ask her to pick six numbered tiles and use them to reach a randomly selected three-digit target. When the time's up, Riley swoops in and scribbles the correct workings. Her degree in maths from the University of Oxford certainly came in handy in this unconventional career.

Now she's encouraging school students to follow suit and take up a science, technology, engineering and mathematics (STEM) subject at university and beyond by launching the Astellas Innovation Challenge. This UK-based competition asks the next generation of would-be entrepreneurs and innovators to design a mobile app geared toward healthy living, and the winning idea will be made into a real-life app. Ahead of the final on 25 November, we caught up with the bubbly brainbox to reminisce about school days and discover which gadgets Riley couldn't live without...

How did you end up becoming a presenter on *Countdown*?
I was always a fan of the show since I was a kid and I love puzzles, but I'd never met anyone who was in TV so I just applied for a laugh, really. I was applying for loads of different grad jobs that summer after I finished my masters degree and most of them were documents that were pages and pages long about when you had worked in a team – blah blah blah – and *Countdown* was just 50 words explaining why you think you'd be good. I had nothing to lose. I didn't expect to get the job, but my mum encouraged me to go for it.

Has there ever been a time when a contestant has got the answer and you haven't?
Not often! (*Laughs*) I've done something like 1,300 shows and we do three or four number games per show so I've done plenty of them now. I'm very competitive with myself but I practise hard.

You must have been very focused at school. Were parents' evenings always a breeze?
(*Laughs*) Yeah! I was lucky that I didn't have to try too hard to get good grades. I was always good at maths but it wasn't my favourite subject growing up. I liked art and PE and then as I got older, the more I studied, the more interesting physics and maths became, because I liked to be challenged. The harder it got, the more of a kick I got out of it.

Why did you study maths at university?
I always loved numbers and puzzles and using my brain. I liked the idea that you had the rules and you could do what you want with them. Physics was the thing I really loved, the applied maths side of things. The rate of change of what people are discovering – the new inventions and technologies – is amazing and I wanted to learn more. If they ever invent a quantum computer, it would change the world!

Rachel Riley's degree in maths helped her land her dream job

Was it your love of technology that drew you to presenting *The Gadget Show*?
Definitely. There's an author I love called Michio Kaku and I read a book of his years ago called *Physics Of The Future*. It was talking about technologies that would be possible in the next ten, a hundred or even a thousand years and some of the things I read about in the book are now in existence.

There are mind-controlled gadgets. I've seen a skateboard that can go up to 50 kilometres [31 miles] an hour just by measuring your brain waves if you're concentrating in the right way. [In 1943], the chairman of IBM thought there would be a worldwide need for five computers and look at where we are now. It's fascinating to thing where we might be in a few years.

Were there any gadgets you bought as a result of doing the show?
I bought things like noise-cancelling, wireless headphones – I love my Parrot Ziks – and I enjoyed playing with different smartphones and tablets. You can use your phone for almost anything now. It's a heart monitor, a tape measure, it can get you from A to B. There are very few things it can't do.

Do you think you'll be using the Google Glass headwear soon?
They are so much fun! We [in *The Gadget Show*] were some of the first people in the UK to try them and they were incredible. Again, in the future-tech books I like to read, they're talking about when this kind of technology will be available on contact lenses, where you've got web screens in your eyes. It's amazing.

Do you think wearable tech will take off?
People are still a bit sceptical and nervous about having a camera pointed at you, but I've used Google Glass and it's amazing to walk around a town and have it direct you. It turns itself off to save battery when you don't need it

and then you can walk past a billboard and you see an instant advert or trailer because it's recognised a QR code. It's scary. Now your wearable tech is connected to your phone, advertisers know where you shop. They know your habits so they can really target you.

The Astellas Challenge is all about creating a healthy living app. What kind of fitness apps do you use?

I use MapMyRide when I go cycling to navigate and see how far I went and how many calories I burned. I'm too lazy for diets but scanning barcodes can be useful.

I used to wear a fitness band and it does make you do more steps. Even though I don't wear it now, I still take the stairs instead of the lift because even though I'm not counting, my body still has the effects of doing a little bit of exercise every day.

There are lots of education apps out there. Is that a good way to nurture a love of subjects like maths?

Absolutely, I've got loads of number and brain-training apps. Your brain is a muscle just like anything else, so you need to train it to keep it sharp. There have been studies that have proven a little bit of brain training can fight off dementia. And in terms of getting kids learning, apps are great because they love games. I've seen kids sit for hours doing timetables and sums during World Maths Day because it was part of a computer game. They were playing against kids all around the world via the internet, which is so much more fun than working from a textbook.

Numbers game

Three of the best maths apps for kids

Number Hero: Multiplication

£1.49/$1.99

Players work backward to solve multiplication problems against the clock and try to beat their highest score.

playMath addition subtraction

Free

Aimed at seven-to-nine-year-olds, this colourful game lets players interact with matters and objects associated to numbers.

Numbers League

£2.49/$3.99

Assemble a team of superheroes and use the sum of their powers to capture villains in Infinity City. Up to four players.

"Your brain is a muscle just like anything else, so you need to train it to keep it sharp"

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

There's a new trip to Mars

The latest NASA mission to Mars is named MAVEN and took ten months to reach Martian orbit. The satellite's task will be to monitor the planet's atmosphere in an attempt to find out why it is so devoid of air. MAVEN will look to find out what effects the Sun has had on the Red Planet's climate throughout history and why Mars has lost all of its water.

World population on the rise

The world population is predicted to reach 12.3 billion by 2100. Previous claims had stated that population growth would stabilize and the number of people on Earth would plateau by 2100, but new research has stated that increased fertility rates and life expectancy, particularly in Africa, is the reason for the rise. As a result, renewed population policies may have to be proposed.

Renewable energy gets a boost

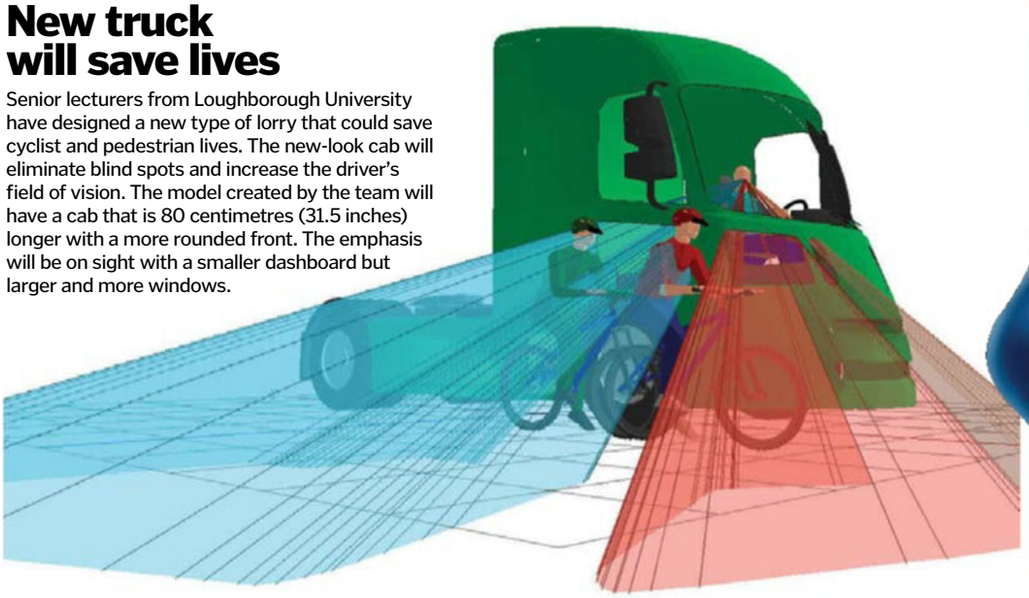
A new type of battery has been made that could be invaluable to future renewable energy production. The lithium-antimony-lead liquid metal battery has the ability to store vast amounts of electricity. Utilising a negative electrode, the battery has a much lower operating temperature than previous designs and will maintain around 85 per cent of its original efficiency even after a decade of daily use.

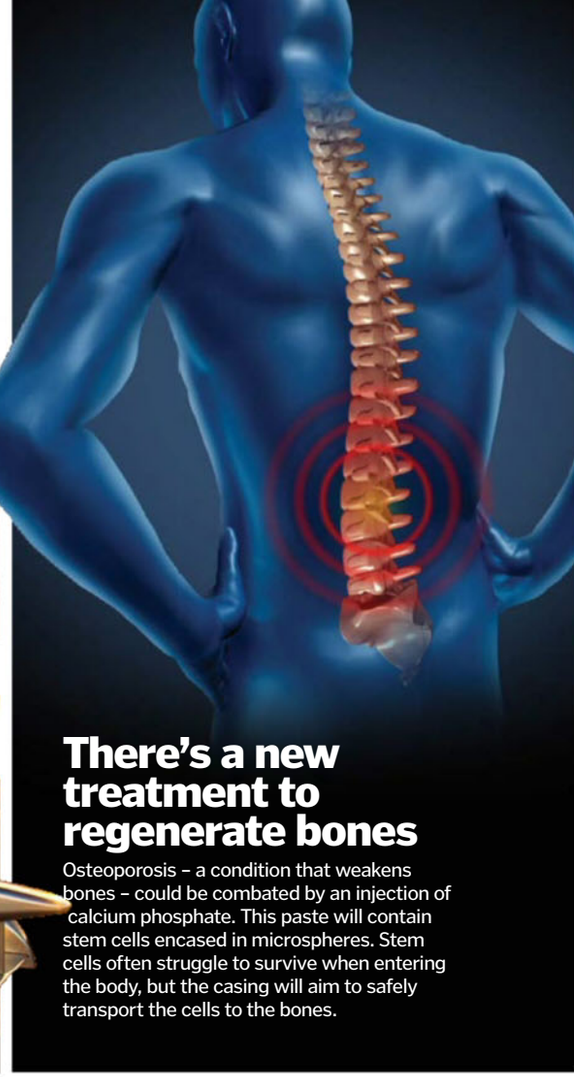
Scientists create a shape-shifting metal

Scientists have created a new type of liquid metal. Formed from an alloy of gallium and indium, the material has a bright future and is being predicted to self-repair electronic structures and circuits. A liquid at room temperature, the alloy is the shape of a ball, but goes flat when exposed to voltage.

New truck will save lives

Senior lecturers from Loughborough University have designed a new type of lorry that could save cyclist and pedestrian lives. The new-look cab will eliminate blind spots and increase the driver's field of vision. The model created by the team will have a cab that is 80 centimetres (31.5 inches) longer with a more rounded front. The emphasis will be on sight with a smaller dashboard but larger and more windows.





There's a new treatment to regenerate bones

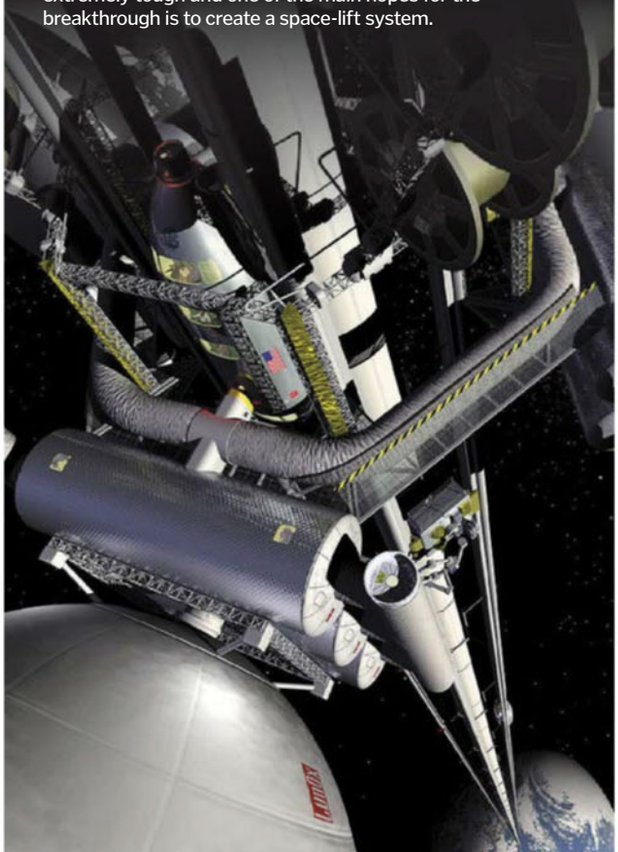
Osteoporosis – a condition that weakens bones – could be combated by an injection of calcium phosphate. This paste will contain stem cells encased in microspheres. Stem cells often struggle to survive when entering the body, but the casing will aim to safely transport the cells to the bones.

All-electric Formula E begins

Electric racing cars took to the streets of Beijing as the first-ever Formula E Championship began. The first of its kind, the competition will look to provide the same thrill ride as Formula 1, but without the carbon emissions. It will run until June 2015.

We could build a lift to space

A real stairway to heaven could be made in the future using the extraordinary properties of diamond nanothreads. The new material was developed by researchers at Penn State University, USA and is composed of a string of carbon atoms. Created under extreme pressure, the nanothread is extremely tough and one of the main hopes for the breakthrough is to create a space-lift system.



There are three types of Europeans

New research has suggested that the European gene pool is created exclusively from three different peoples: blue-eyed hunters, brown-eyed farmers and an influx of groups from Siberia. The findings were discovered by analysing genomes and shows that Europe was originally an area of blue-eyed hunter-gatherers before the arrival of brown-eyed farming communities from the east around 7,500 years ago.

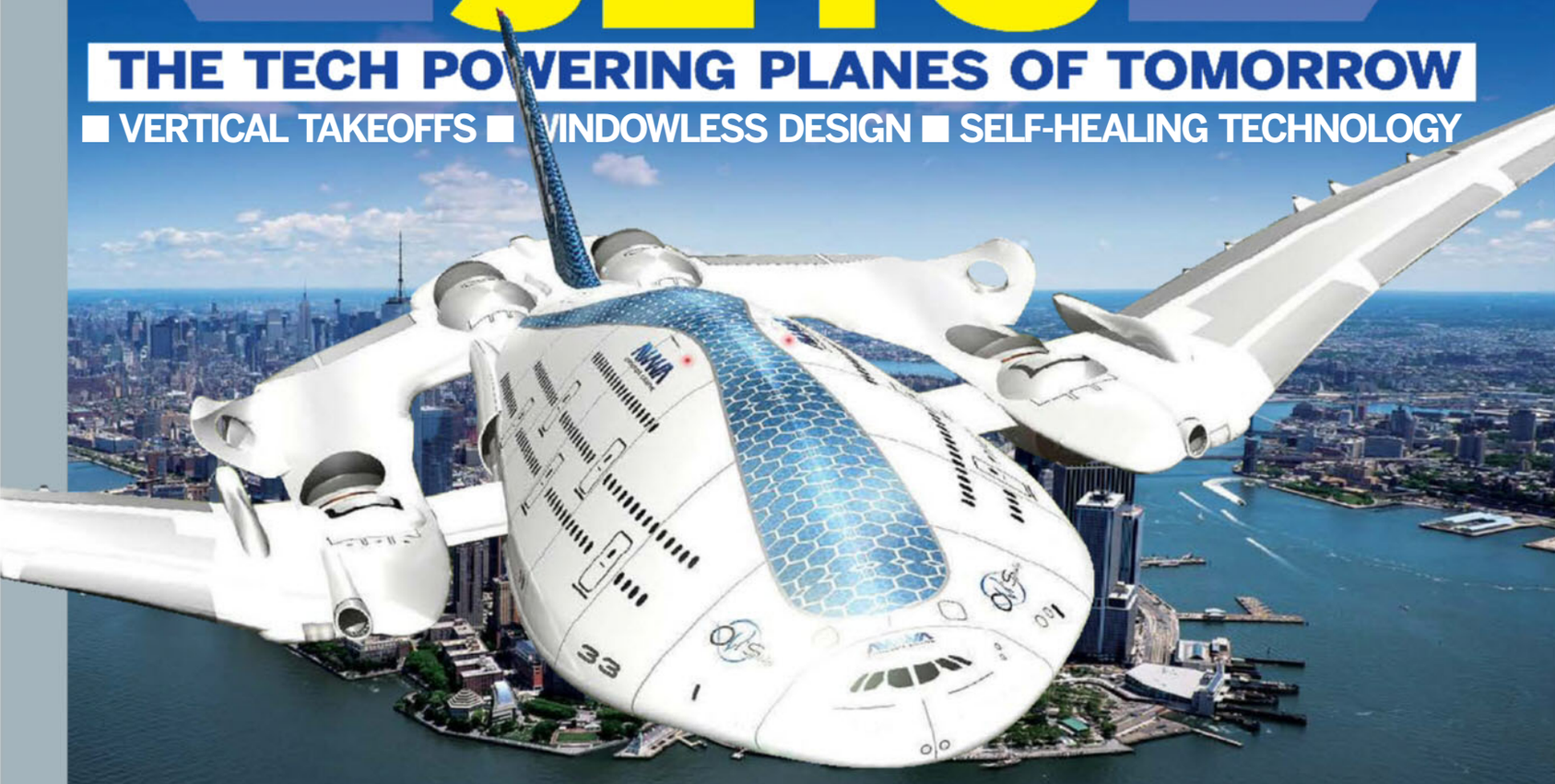
Brains have their own (free) 'calorie counters'

Our brains naturally works out the calorie content of different foods when we look at a menu. That's according to neuroimaging research, which sought to determine how our awareness of calories influenced the brain. The study found that although calorie estimations were off the mark, people were willing to pay high prices for high-calorie food, showing their desire to consume it.

SUPER JETS

THE TECH POWERING PLANES OF TOMORROW

■ VERTICAL TAKEOFFS ■ WINDOWLESS DESIGN ■ SELF-HEALING TECHNOLOGY



On 1 January 1914, the world was changed forever when the first commercial flight took off. It flew between the cities of St Petersburg and Tampa in the state of Florida in the United States, lasting a total of 23 minutes and covering a distance of 33.8 kilometres (21 miles).

This landmark event came 11 years after the famous Wright brothers' first powered flight, and marked the first time someone paid to be a passenger on an aircraft. The plane was the boat-like Benoist XIV, which only had room for the pilot and the auction-winning bidder, who coughed up a healthy $400 for the experience. That would be over $9,500 (£5,850) in today's estimated currency value.

Today, people are likely to pay over 100 times that initial amount for a ticket on a suborbital flight. These space planes will take their passengers into orbit, cutting the time from London to the US west coast down to an astonishing 60 minutes. However, it's not just the passengers that are getting a boost. Plans are well under way for smartplanes that can sense when they've got a problem and even heal themselves mid-flight.

The last 100 years have seen startling improvements in commercial aeroplane technology, such as enormous double-decker jets that can carry up to 853 passengers in a single haul, planes that can circle the world in less than two days and, of course, the legendary Concorde that took over 2.5 million people through the sound barrier.

Over the next few pages, we look to the next century of sparkling innovation to see what the aircraft of the future might look like. Commercial flight has come a million miles from that first wooden biplane journey, so buckle up, put your tray into the upright position and please stay seated for the duration of your journey. ▶

5 TOP FACTS
DOUGLAS DC-3

Bunk beds
1 The first DC-3 had 14 seats that folded into seven beds, while seven more dropped down from the ceiling to provide sleeping berths for 14 people.

Market leader
2 The Douglas DC-3 was so ahead of the competition it was estimated that 90 per cent of all aeroplane journeys were on Douglas DC-2s and DC-3s.

Into war
3 The DC-3 played a vitally important part in WWII as a transport aircraft for troops, supplies and vehicles, thanks to its size, strength and durability.

Setting records
4 The DC-3 was the first commercial airliner with the fuel capacity to make a nonstop journey between New York and Chicago in the United States.

Experience
5 It took a two-hour, $300 long-distance phone call from American Airlines president Cyrus Rowlett Smith to convince Donald Douglas to make the DC-3.

DID YOU KNOW? *The passenger on the first commercial flight was the former mayor of St Petersburg. He paid $400 for the flight*

SKY WHALE

Design: Oscar Viñals

Is this three-storey concept vehicle the future of travel?

The Airbus A380 currently holds the title for the biggest passenger plane, but that could all change. Called Sky Whale, this concept aeroplane would have a wingspan of 88 metres (289 feet), compared to the A380's 80 metres (262 feet). It would seat 755 passengers, making it economically viable for airlines. The Sky Whale would be able to fly further without refuelling thanks to a double fuselage, and solar cells on the wings would harness power from the Sun. Designed by Oscar Viñals, the aircraft also boasts innovative features such as tilting engines for near-vertical takeoffs. Visit www.behance.net/ovisdesign for more.

During a crash landing, the wings would separate from the body

Solar cells draw power from the Sun

First class will have unbeatable sky views

755 Seats on three levels

Virtual reality windows

Laser guidance system

Near-vertical takeoff ability

The Sky Whale is a radical reimagining of the commercial aeroplane

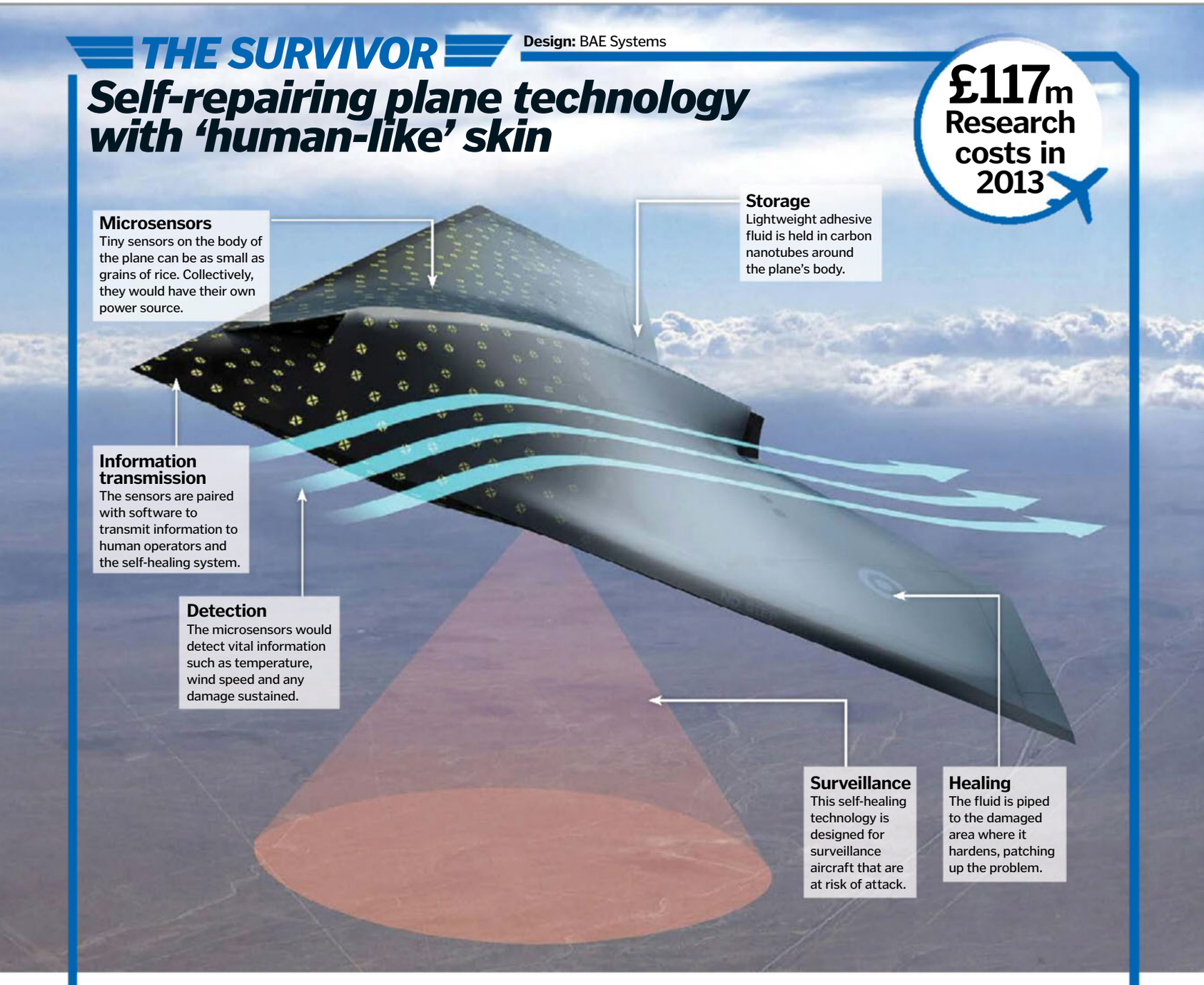
"The last 100 years have seen startling improvements in commercial aeroplane technology"

THE SURVIVOR

Design: BAE Systems

Self-repairing plane technology with 'human-like' skin

£117m Research costs in 2013



Movies like *The Terminator* may have warned us not to create technology that can heal itself, but the folks at BAE Systems decided to press on regardless. The UK company has unveiled futuristic designs that could revolutionise the method – and speed – that planes are repaired by 2040.

The aircraft's body would be covered in tens of thousands of microsensors that detect wind speed, temperature and any damage sustained. The craft would be able to heal itself in mid-air thanks to a grid of carbon nanotubes that hold a lightweight adhesive fluid. This would be released to the damaged area and quickly harden – like blood forming a scab on a cut – enabling the craft to continue its flight.

This advanced use of materials would create an extremely hardy jet capable of entering the most dangerous of scenarios to complete vital missions, according to a BAE Systems spokesman. They are calling it The Survivor, and that's not the only technology the company believes could be incorporated in military aircraft in the future. Another type of jet, known as The Transformer, would combine smaller sub-aircraft during travel and then split off. This would increase range and save fuel by reducing drag when they fly together.

Despite edging us ever closer to Skynet, this technology is hugely exciting for the aviation industry as smart planes would send maintenance costs and times plummeting, leaving us much more time to plan how to prevent them from rising up against us!

What inspired BAE's smart-skin?

A Lizard **B** Tumble dryer **C** Chicken pox

Answer:
Lydia Hyde, senior research scientist at BAE, was watching her tumble dryer and noticed it had a sensor to stop it overheating. This got her thinking that if a domestic appliance has this technology, aeroplanes could too.

DID YOU KNOW? *BAE is looking into 3D printing unmanned aircraft on board in order to respond faster to mission changes*

SMARTER SKIES

Design: Airbus

The most energy-efficient plane on the planet

Airbus has always been at the forefront of aviation technology and its futuristic Smarter Skies concept aims to be more efficient and eco-friendly. Here are a few ways in which it's hoping to make future air travel better for passengers and the environment by 2050.

9mn Tons of fuel that could be saved

Learn more

To have a good look around the most futuristic cabin ever, download The Future By Airbus app for free from iTunes. It gives you a virtual tour of the flight you could be catching in around 35 years.

ECO-CLIMB

Electromagnetic motors built into the runway would save fuel and reduce noise pollution. They could launch the plane into the air on take-off and capture it as it lands, slowing it down safely. This would save fuel by removing the need for heavy landing gear, but would require every airport to have the same system.

CONCEPT CABIN

Airbus is looking to do away with cramped seats, narrow aisles and class warfare. Instead, planes will be split into zones, such as a relaxation zone, an interaction zone and a smart tech zone. The latter could hold seats made of materials that have a 'memory', morphing to each passenger's body shape.

BETTER TOGETHER

Birds flying in their V formation reduce drag by up to 65 per cent. Airbus is proposing planes on popular routes could club together and fly in formation, reducing fuel burn by ten to 12 per cent. That could save over 10,000 litres (2,640 gallons) of fuel on a journey between London and New York.

"Our plan is to [...] fit 4K HD cameras to the wings and body that can display images of whatever's outside"

IXION **Design:** Technicon

Panoramic views that bring the outside in

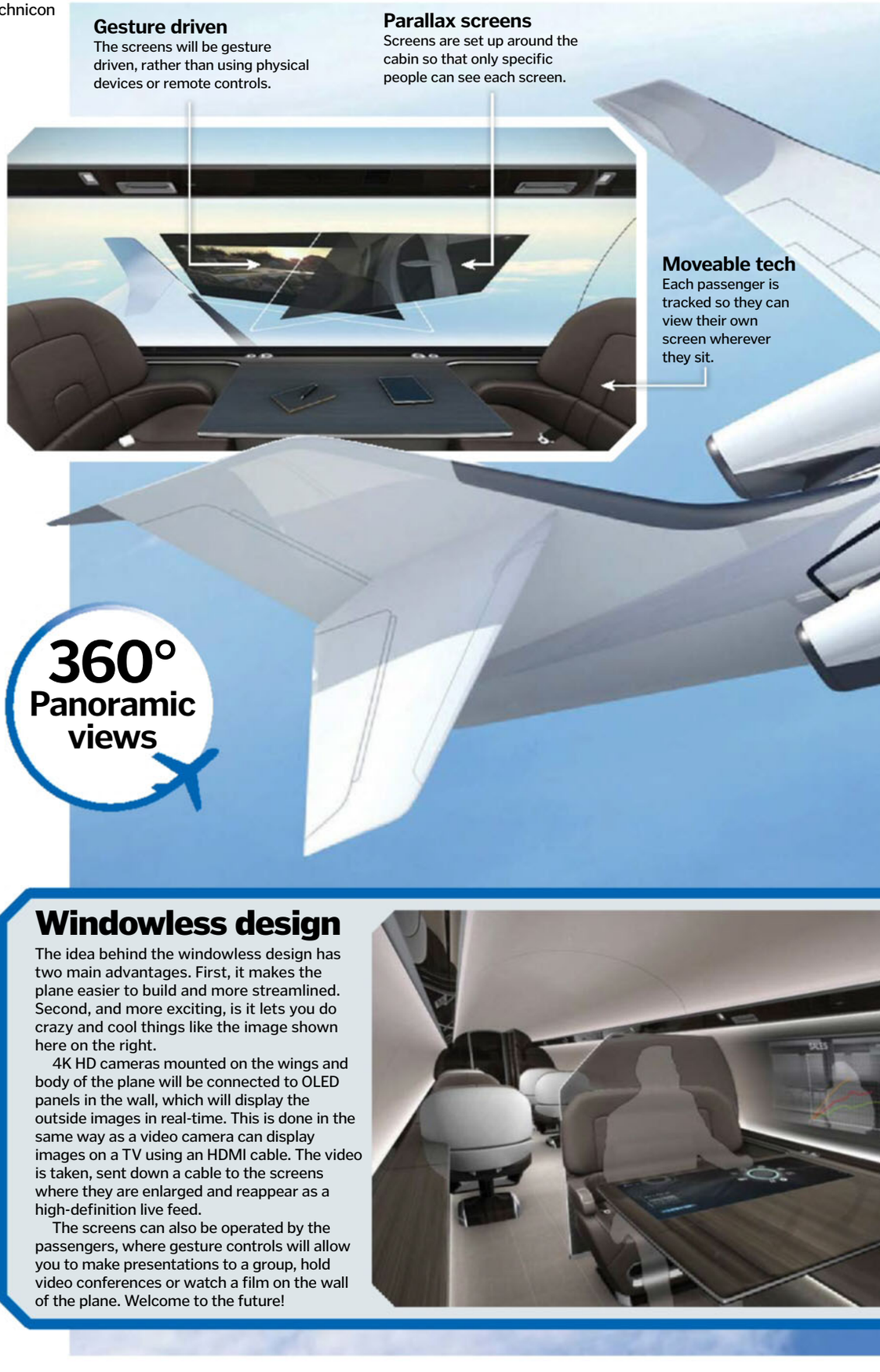
Apart from using newer materials and streamlining, actual aeroplane design has changed very little over the years. However, Technicon Design is an international company trying to change all that with its concept of a windowless jet called the IXION.

Gareth Davies, design director at Technicon Design, explains his vision for future planes: "Windows are complicated things to put into aeroplanes. Each window can add 15 kilograms (33 pounds) to the overall weight and they're not aerodynamic. Our plan is to remove the windows and fit 4K HD cameras to the wings and body that can display images of whatever's outside onto flexible OLED screens inside the plane."

This would give an uninterrupted panoramic view from the inside, while reducing weight and simplifying construction. A myriad of potential cabin moods and themes would be opened up: "You'll be able to control what is displayed on the screens from your smartphone." This could result in a future where passengers travelling over a featureless ocean could be treated to sights like the New York skyline, a desert or even Godzilla taking on downtown Tokyo.

If you don't fancy looking at the same view as everyone else, the concept also suggests parallax screens that can only be seen by the person sitting in a particular seat. To create a truly flexible seating arrangement, passengers would be tracked so their screen follows them to whatever seat they sit in.

Solar panels would also be employed to power internal electronics. This would generate alternative power for the low-voltage systems on board when the engines are idle and save five per cent of the total fuel used. The designs challenge conventional thinking on every level. "We wanted to imagine a possible next step forward", he continues. "The first stage in any innovation is imagination."



Windowless design

The idea behind the windowless design has two main advantages. First, it makes the plane easier to build and more streamlined. Second, and more exciting, is it lets you do crazy and cool things like the image shown here on the right.

4K HD cameras mounted on the wings and body of the plane will be connected to OLED panels in the wall, which will display the outside images in real-time. This is done in the same way as a video camera can display images on a TV using an HDMI cable. The video is taken, sent down a cable to the screens where they are enlarged and reappear as a high-definition live feed.

The screens can also be operated by the passengers, where gesture controls will allow you to make presentations to a group, hold video conferences or watch a film on the wall of the plane. Welcome to the future!

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Take a tour around the mind-boggling IXION jet

www.howitworksdaily.com

DID YOU KNOW? *Parallax tech is responsible for webpages that move at different speeds as you scroll down, creating a 3D effect*

Smartphone enabled
Images from a smartphone can also be displayed on the screens.

Bringing the outside inside
The images from the external cameras will be displayed on OLED screens inside the plane.

Solar panels
Internal electronics will be powered by solar panels on the plane's body.

OLED screens
Thin, flexible plastic screens replace the traditional porthole windows, giving passengers panoramic views.

Windowless body
The lack of windows makes the IXION easier to build, lighter and more streamlined.

Passengers could be treated to a panoramic view of the world outside their plane. Would you dare look down?

Cameras
4K HD cameras will take real-time video of the world outside the plane.

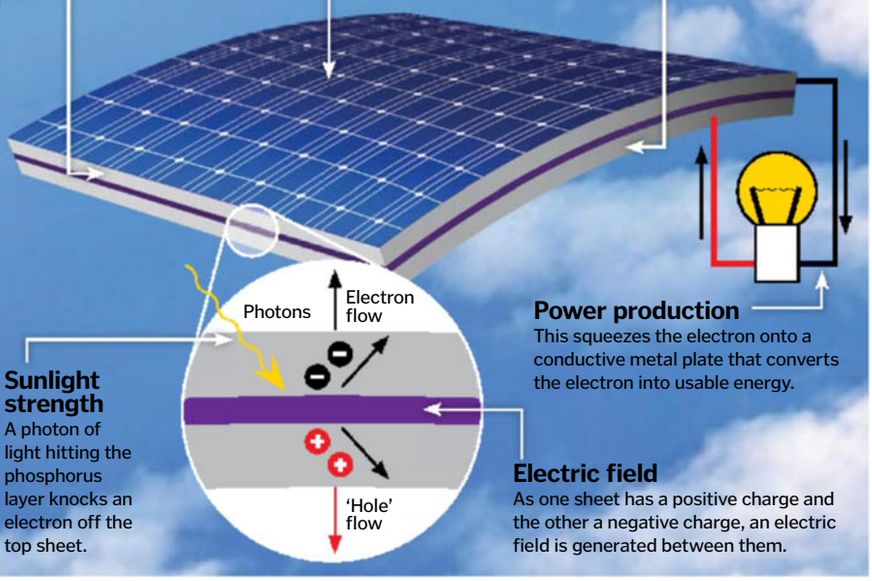
Solar-powered planes

How planes harness the Sun's energy

Silicon sandwich
A solar panel is made up of two sheets of silicon, split up into lots of photovoltaic cells.

Top layer
The top layer is coated with phosphorus, which increases the number of free electrons on that side.

Bottom layer
This layer will be coated with boron, which decreases the number of free electrons.



Power production
This squeezes the electron onto a conductive metal plate that converts the electron into usable energy.

Sunlight strength
A photon of light hitting the phosphorus layer knocks an electron off the top sheet.

Electric field
As one sheet has a positive charge and the other a negative charge, an electric field is generated between them.

"This would allow it to reach Australia from Europe in as little as 90 minutes from takeoff to landing"

SPACE PLANES

Boldly going where no commuter has gone before

While travelling faster than the speed of sound, Concorde made it from London to New York in around three hours. However, that's sloth-like compared to the space plane aiming to travel from Europe to Australia in half that time.

That craft is SpaceLiner, being developed the German Aerospace Center. This 83.5-metre (274-foot) long craft could carry up to 100 passengers up to 80 kilometres (50 miles) into the air, gliding in sub-orbit at over 20 times the speed of sound. It would be delivered into the higher layers of our atmosphere by LOX/LH_2 (liquid oxygen and liquid hydrogen) rockets before disengaging at nearly four kilometres (2.5 miles) per second. This would allow it to reach Australia from Europe in as little as 90 minutes from takeoff to landing.

Also on the horizon are the Virgin Galactic and Skylon space planes, which are looking to go directly up from – rather than around – the Earth. Virgin Galactic's SpaceShipTwo will be launched from a jet-powered plane. It will take passengers into space for a few minutes before returning to Earth. Skylon, on the other hand, is an unmanned, reusable space plane designed to carry 15 tonnes of cargo into outer space and return. This would make it much easier and cheaper for private companies to send cargo into space for use on satellites and space stations.

They used to say the sky's the limit, but the next generation of passenger and cargo planes have shown that it's only the beginning.

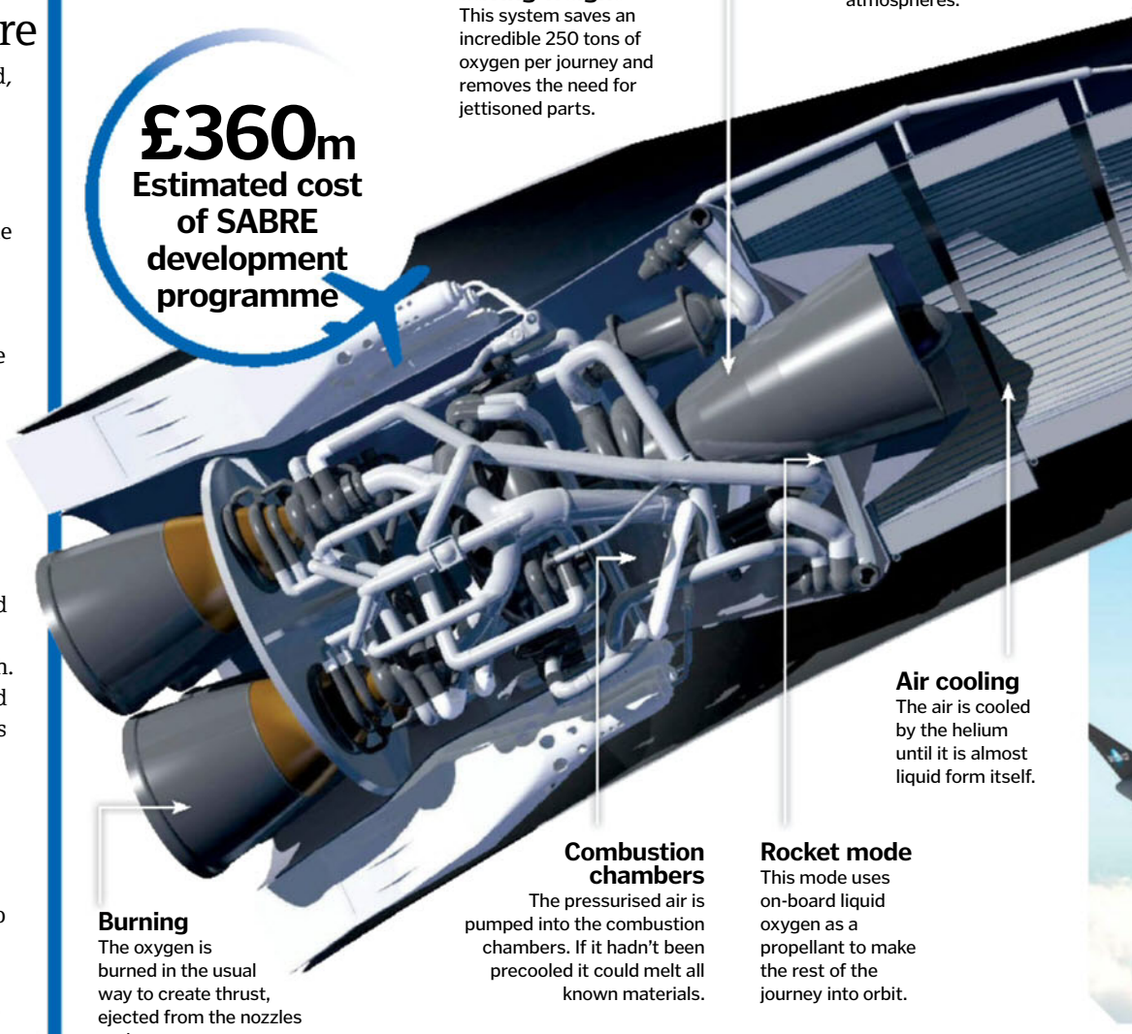
SKYLON

Design: Reaction Engines Ltd

Inside the SABRE engine

What is powering this new, reusable rocket Skylon?

£360m
Estimated cost of SABRE development programme



Compression
The air is compressed until it reaches 140 atmospheres.

Saving weight
This system saves an incredible 250 tons of oxygen per journey and removes the need for jettisoned parts.

Air cooling
The air is cooled by the helium until it is almost liquid form itself.

Combustion chambers
The pressurised air is pumped into the combustion chambers. If it hadn't been precooled it could melt all known materials.

Rocket mode
This mode uses on-board liquid oxygen as a propellant to make the rest of the journey into orbit.

Burning
The oxygen is burned in the usual way to create thrust, ejected from the nozzles at the rear.

VIRGIN GALACTIC

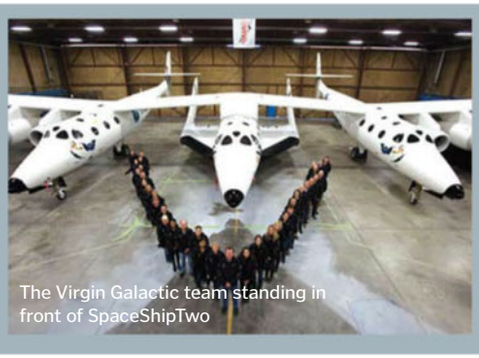
Design: Scaled Composites

Richard Branson announced to the world in 2004 that he would be sending tourists into space, making Virgin Galactic the first commercial space plane. However, despite original plans to launch a flight in 2007, Virgin Galactic is yet to take its first batch of space tourists into the Solar System.

The ship will be carried to a height of 15,240 metres (50,000 feet) by the support craft WhiteKnightTwo. The crafts will detach and the passenger ship will fire its rockets to take its passengers out of the Earth's atmosphere and into space.

After four to five minutes it will re-enter the Earth's atmosphere, coming back to land on the runway at its New Mexico base.

The technical and logistical hitches that have set the programme back are being resolved, with the Federal Aviation Administration (FAA) clearance a major hurdle overcome in May 2014. Hopefully, the journey to outside our atmosphere is just around the corner.



The Virgin Galactic team standing in front of SpaceShipTwo

KEY DATES
HISTORY OF VIRGIN GALACTIC

2004
Sir Richard Branson announces Virgin Galactic and begins taking applications for passengers.

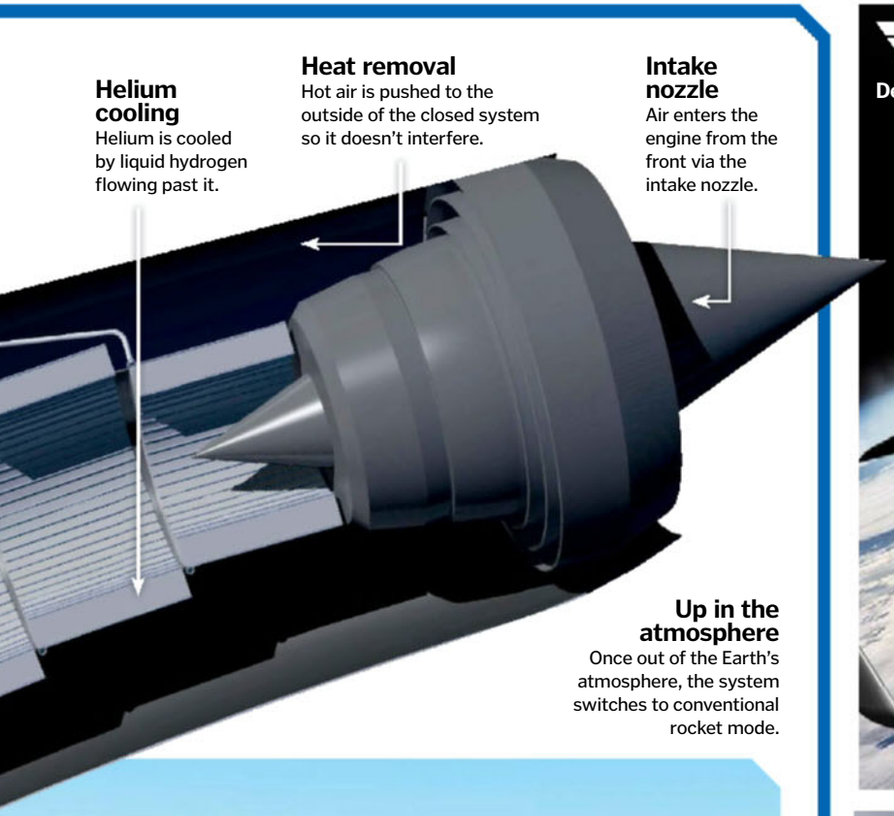
2005
Branson confirms the project, saying that the new spaceship will provide a zero-gravity experience for six passengers per trip.

2007
The spaceport in New Mexico from which Virgin Galactic is to be launched is designed.

2008
SpaceShipTwo, the spaceship, is revealed to the press and public. It's attached to WhiteKnightTwo, the carrier.

2011
WhiteKnightTwo successfully carries and launches SpaceShipTwo from 15,700m (51,500ft).

DID YOU KNOW? *Many celebrities like Leonardo DiCaprio and Stephen Hawking are reportedly on Virgin Galactic's passenger list*




What the Skylon will look like when it soars above our skies

$250,000 Virgin Galactic ticket cost


SpaceShipTwo has already flown several test flights


SpaceShipTwo has a hybrid-power rocket motor

SPACELINER
Design: German Aerospace Center


A concept drawing of what the SpaceLiner will look like

London to Sydney in 90 minutes

We spoke to Olga Trivailo who works at the German Aerospace Center to explain what is in store for future long-distance fliers

How exactly will the proposed SpaceLiner work?
It will use standard rocket technology such as liquid hydrogen and oxygen-fuelled rockets to accelerate to Mach 25. Once it is at 70 to 80 kilometres (43.5 to 50 miles) high, the booster will detach and return to the launch site. The craft will then glide all the way to its destination.

Does the lack of gravity or wind resistance play a part in its speed?
No. It cuts travelling times so much purely because it is travelling so fast from the rocket boost. It needs to go that high to go that fast so it can get the full benefit from the rocket's speed.

What sets the SpaceLiner apart from other flight options?
The reusability is a major part in the SpaceLiner programme. The fact that we will be able to reuse both parts of the rocket makes it much more viable as a business.

What kind of market are you looking at then?
Initially we want to target the business-class passengers who need to travel long distances and want to cut down their time. A trip to Australia from Europe [currently] takes over 24 hours when you count transfer time and when you get there, you just don't feel human. I feel this will really benefit mankind as SpaceLiner could also be used to transport time-sensitive cargo, such as organs.

Will everyone be able to use it, or just the extremely physically fit?
Anyone who is reasonably healthy can travel on it. At take-off you would experience at most 2.5 g. To put this into perspective, a normal flight could create up to 1.25 g and some roller coasters experience 5 g.

When are we expecting it to come into service?
If we're being realistic, in around 30 to 35 years. We need that time because, even though the rocket technology is there, we need to make it safe for the public to use. This means finding materials that can deal with the heat of the Earth's atmosphere and making the passenger pod capable of turning into an emergency escape pod in the unlikely event of an accident.

"The technology acts as an electronic system balancing the optimum ratio of power with enough traction"

How launch control works

This clever technology optimises power and traction for the perfect getaway in a racer or supercar

The technology acts as an electronic system balancing the optimum ratio of power with enough traction to ensure the car is launched forward from standstill with minimal wheelspin, for a clean, quick getaway. To do this, the system allows an input of an optimum amount of engine revs that will provide huge but not overzealous power. A quick and precise 'dumping' of the clutch is then performed (taking away the possibility of sloppy or mistimed starts from human input).

Meanwhile, the drive shafts are lavished with sensors and computers constantly calculating the amount of torque available at each axle. If the computer realises there's too much power available for the wheels to keep traction, then power is electronically adjusted within milliseconds. Launch control takes into account many factors including road surface, engine temperature, tyre temperature and tyre pressure, as these are all variables that can affect the outcome of a rapid start.

Originally implemented on high-profile racecars (including Formula 1), the technology has found its way onto road-going supercars such as the Ferrari 458 or Porsche 911 Turbo. What's more, the technology is incredibly user-friendly, with the driver commonly only having to operate two pedals to initiate and then execute the launch-control technology.

If you look through the history of any supercar manufacturer such as Ferrari, Porsche, or Lamborghini, you won't fail to notice how their vehicles have constantly gotten faster and faster, with big 'top-end' speeds complemented by ever-shorter 0-to-60-mile-per-hour sprint times. Making more powerful engines has proven relatively straightforward for manufacturers then, but sheer power is nothing without grip to the road.

Keeping traction

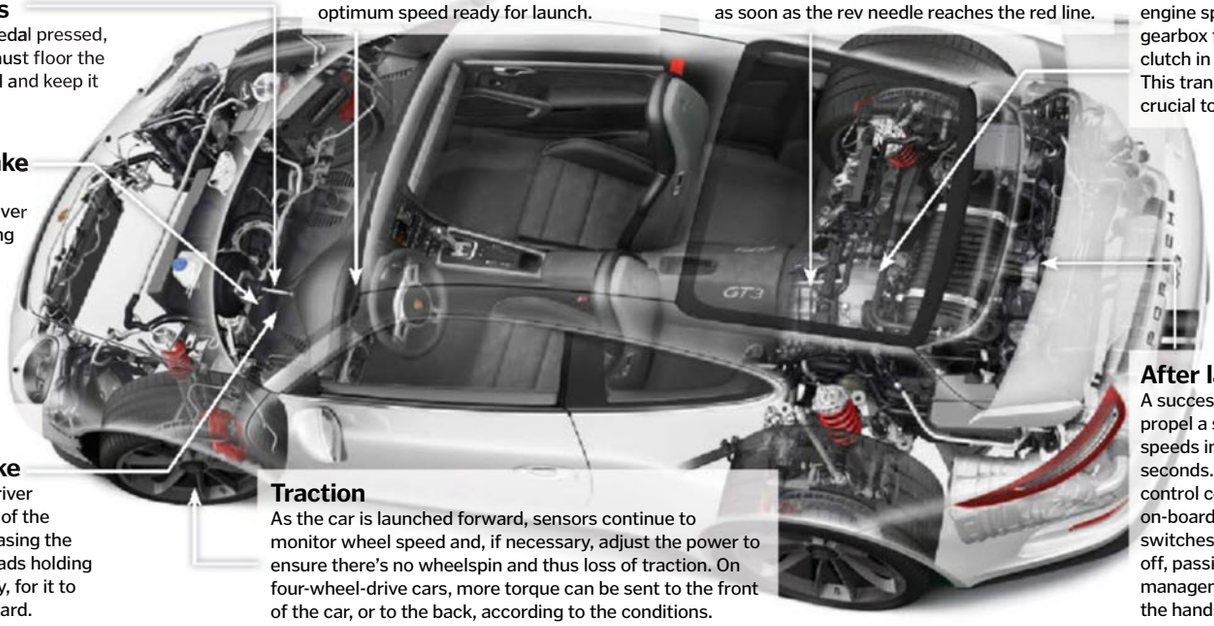
With supercar engines now more powerful than ever, ensuring they keep traction with the road has become ever-more crucial for both performance and safety. Most supercars now come with active suspension management, which allows the driver to deploy a firmer ride at the switch of a button. With less 'bump and rebound' from the suspension, the car follows the exact contours of the road rather than effectively riding over them, which aids traction.

More astute technology, including individual wheel braking around corners and torque vectoring, helps to electronically spread torque more evenly between the front and rear axles (most supercars are now four-wheel drive for more even power distribution) to ensure a greater balance of grip.

Downforce is also crucial to traction, and many supercars now feature active aerodynamics, which changes the rate of downforce according to speed, keeping the car as hunkered to the road as possible.

Blast off!

Launch control does all the hard work to ensure the perfect start



Floor the gas

With the brake pedal pressed, the driver then must floor the accelerator pedal and keep it pinned down.

Hold the brake

In an automatic sportscar, the driver begins by pressing and holding the brake pedal with his left foot. The supercar is stationary.

Release brake

From here, the driver just has to let go of the brake pedal, releasing the clamped brake pads holding the car stationary, for it to then launch forward.

Launch control activated

The onboard computer recognises the launch control and notifies the driver on the clock. Engine revs are held at optimum speed ready for launch.

Changing gears

As launch control is so fast, most cars with the feature are equipped with an automatic gearbox. This will change up gears from liftoff as soon as the rev needle reaches the red line.

Dumping the clutch

The computer seamlessly and precisely passes engine speed to the gearbox for drive via the clutch in milliseconds. This transfer of power is crucial to any start.

Traction

As the car is launched forward, sensors continue to monitor wheel speed and, if necessary, adjust the power to ensure there's no wheelspin and thus loss of traction. On four-wheel-drive cars, more torque can be sent to the front of the car, or to the back, according to the conditions.

After launch

A successful launch will propel a supercar to big speeds in a matter of seconds. With launch control completed, the on-board computer switches the technology off, passing traction management back into the hands of the driver.

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"Since a PWC weighs as much as five adults, the engine has to be really powerful"

Personal watercrafts

The physics of skimming across the waves

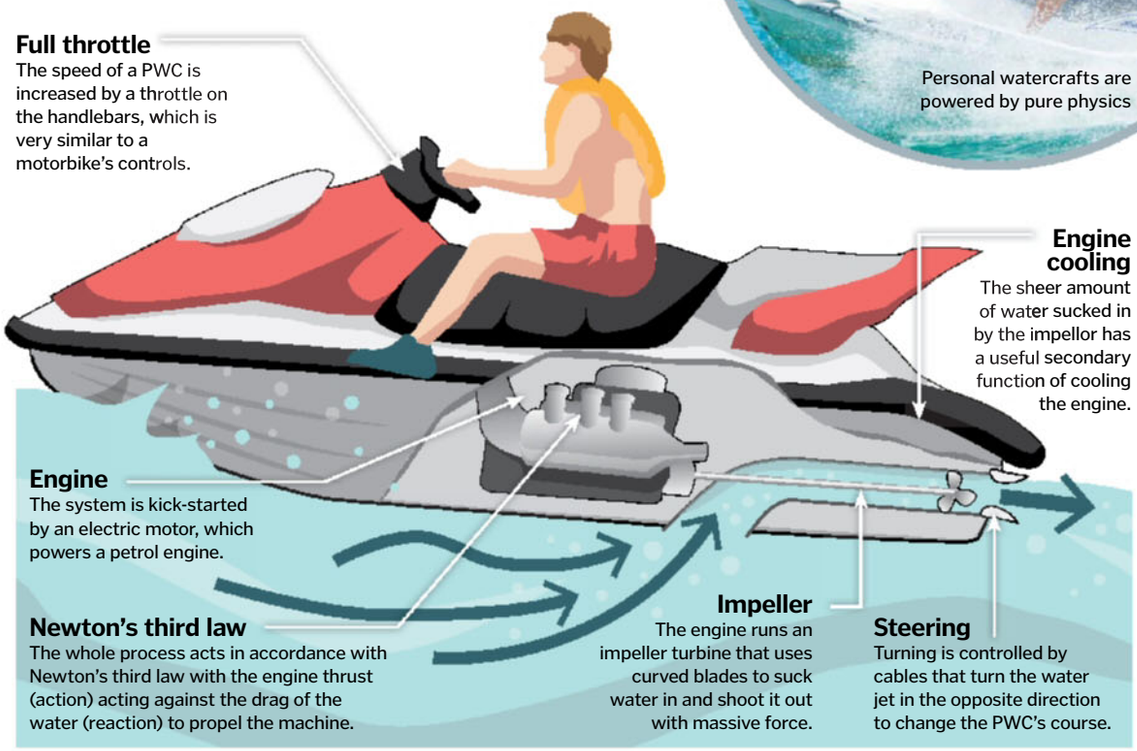
You probably know these high-powered machines as Jet Skis, but that's just a brand name. The real term is a personal watercraft (PWC) and they can hit speeds of over 100 kilometres (62 miles) per hour and churn out around 220 kilowatts (300 horsepower) of power as they zoom across the water.

Since a PWC weighs as much as five adults, the engine has to be really powerful. The engine tasked with reaching these speeds uses Newton's third law of motion, which states that for every action there is an equal and opposite reaction. A PWC works by sucking water through a grate at the bottom of the craft and shooting it out the back. This force pushing backward from the engine propels the craft forward. It's similar to when you're swimming front crawl, pulling back with your arms in order to keep moving. Rocket engines actually work based on the same principle, using hot gas instead of water.

Personal watercrafts are powered by pure physics

How PWCs work

The physics and equipment at work to enable you to play



Full throttle
The speed of a PWC is increased by a throttle on the handlebars, which is very similar to a motorbike's controls.

Engine cooling
The sheer amount of water sucked in by the impellor has a useful secondary function of cooling the engine.

Engine
The system is kick-started by an electric motor, which powers a petrol engine.

Newton's third law
The whole process acts in accordance with Newton's third law with the engine thrust (action) acting against the drag of the water (reaction) to propel the machine.

Impeller
The engine runs an impeller turbine that uses curved blades to suck water in and shoot it out with massive force.

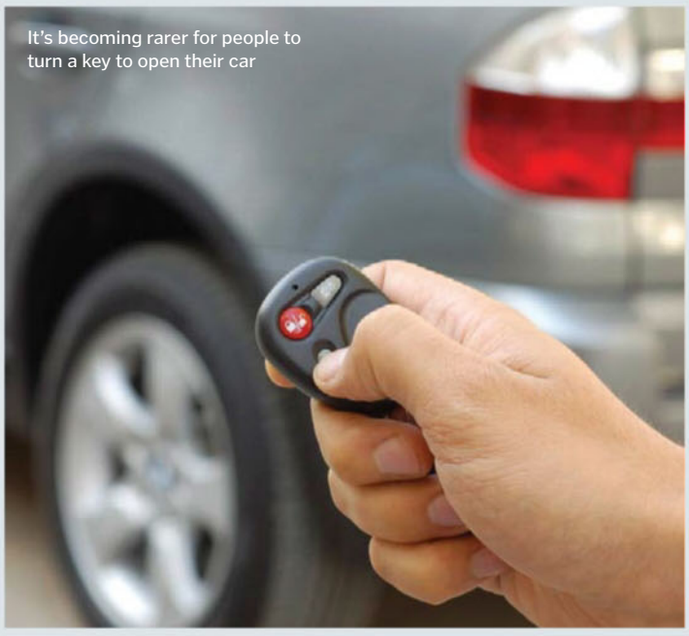
Steering
Turning is controlled by cables that turn the water jet in the opposite direction to change the PWC's course.

Keyless entry

How this technology uses frequencies to unlock our vehicles

Keyless entry enables a user to unlock and enter a vehicle without the need to use a requisite key. The system works by a paired ID sender in the form of a radio transponder chip inside the key interacting with sensors around the car. Each vehicle is issued with its own pairing programme, working on its own frequency, and the chip in the key must be in range of the sensors in the vehicle. The pairing is usually recognised when the chip is several metres away from the sensors, which are dotted all around the vehicle, when the driver clicks the 'unlock' button.

Keyless entry now a ubiquitous feature on most if not every car built, as it enables quick and hassle-free entry to a vehicle (especially when there's more than one door to unlock), and is also considered safer to use as an owner can be sure that every door on the vehicle is either locked or unlocked at any one time.



It's becoming rarer for people to turn a key to open their car

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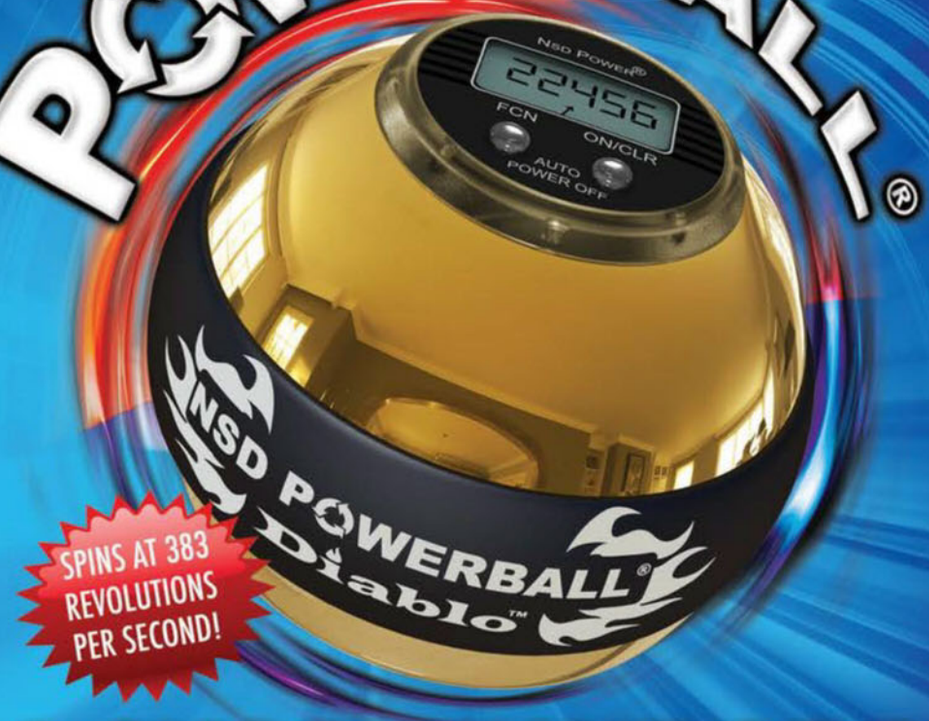

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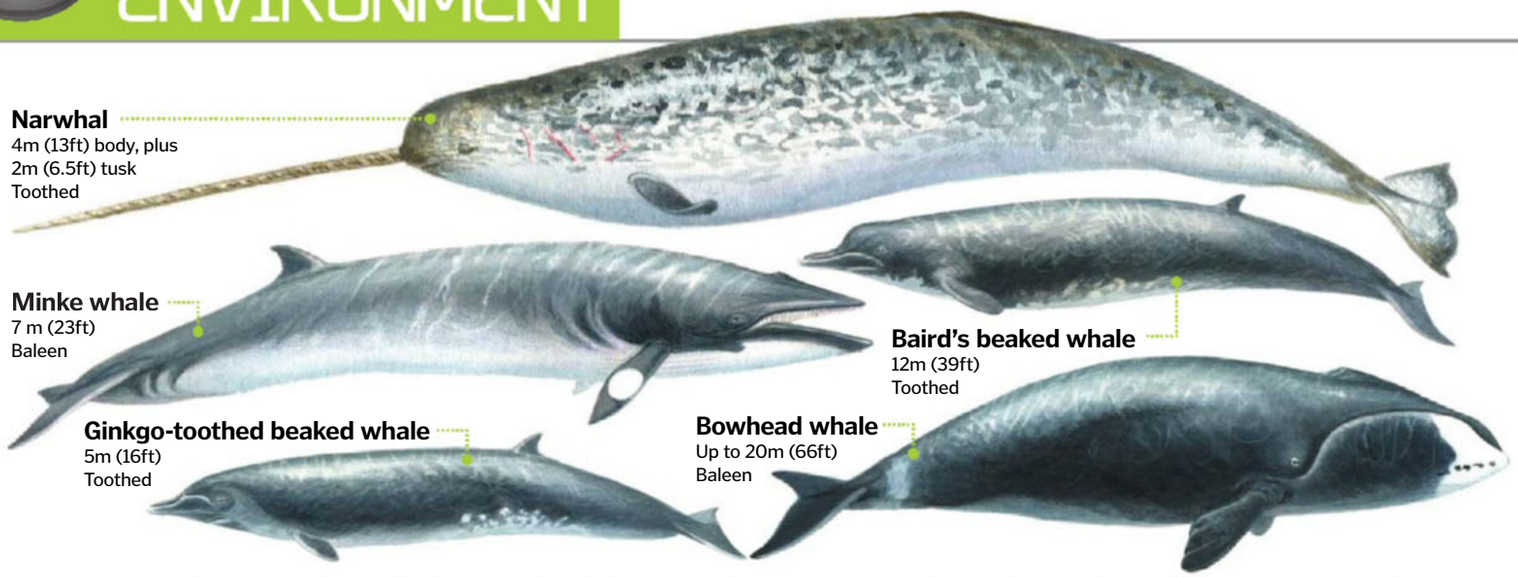


THE SECRET LIFE OF WHALES

TAKE A DEEP BREATH AND DIVE INTO THE MYSTERIOUS WORLD OF NATURE'S OCEAN GIANTS

5 TOP FACTS
WHALE OF FORTUNE

1 Humpback culture
The song of the humpback whale adapts over time. New phrases get added in and the 'trend' quickly spreads as other male whales all adopt the new song changes.

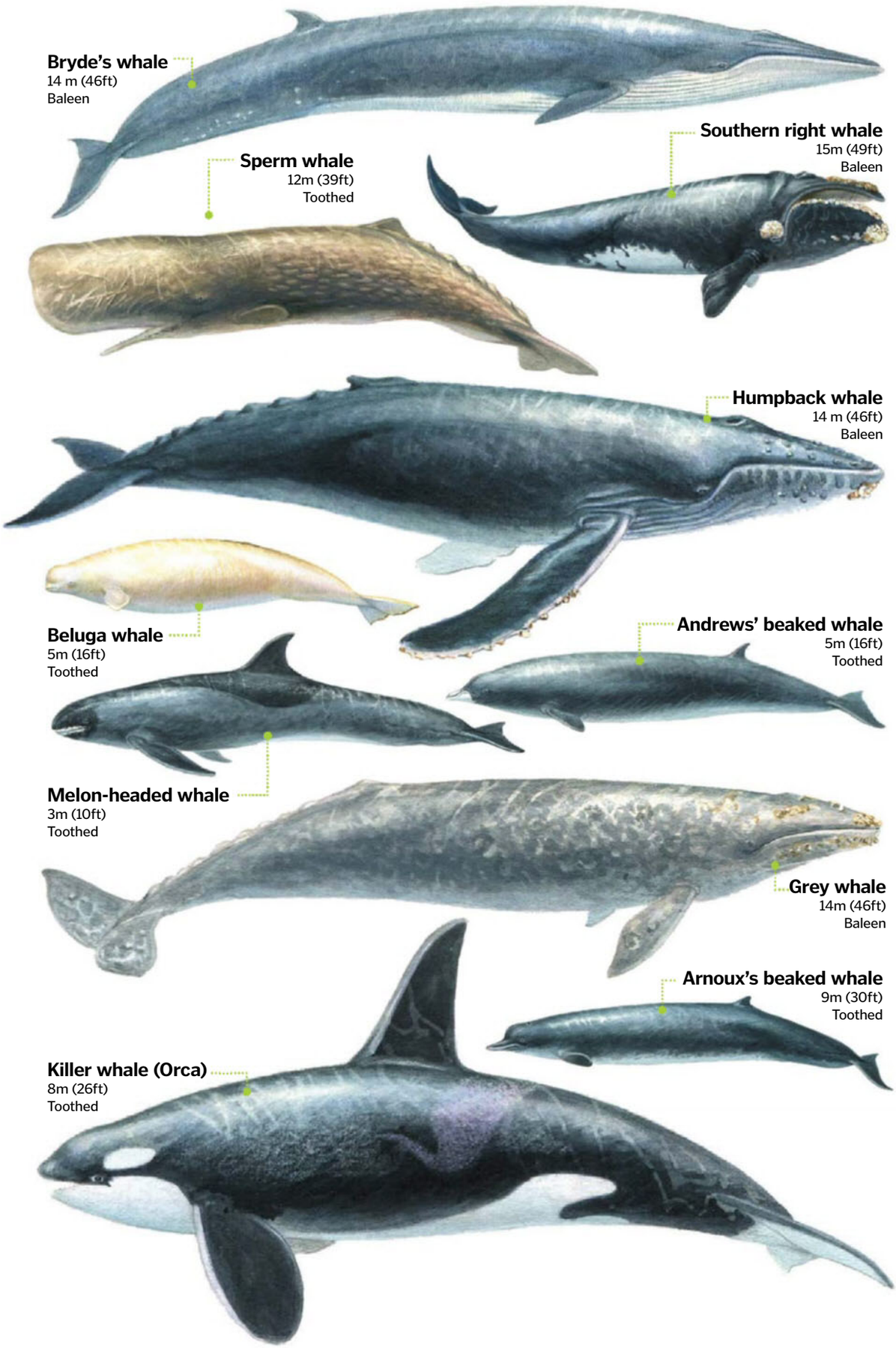
2 Blowhole adaptations
Baleen whales have a double blowhole and toothed whales have a single one. It's thought the double blowhole is to facilitate oxygen intake for the whales' huge size.

3 Unicorn of the sea
The narwhal is an amazing species related to the Arctic beluga whale. It has a huge tusk that protrudes from its head like a unicorn – this is actually a modified tooth!

4 Deepest-diving whale
The Cuvier's beaked whale has recently set the record for the longest and deepest whale dive, at 137.5 minutes to a depth of 2,992m (9,816ft).

5 Whale poo is valuable
Ambergris is a waxy product formed in sperm whale intestines, and is very rare. This substance is also a key ingredient in perfume, and is almost worth its weight in gold!

DID YOU KNOW? *A humpback's mouth can expand to fit a small car, but its throat is only about the size of a grapefruit*



With around 78 species found on our planet, whales are fascinating and enigmatic creatures. Intelligent and endearing, there's something about these ocean leviathans that can't help but captivate us.

The largest animal to ever exist on Earth is swimming in our oceans right now. The blue whale measures a whopping 32 metres (105 feet) long and weighs up to 200 metric tons. Its tongue alone is as heavy as an elephant, but despite its gigantic size, it's a mammal just like us. Whales are warm-blooded, they breathe air, and need to come to the surface to take a fresh breath before diving to the depths again. They give birth to live young, have an amazing social structure and even show a degree of emotional intelligence. When put like that, whales don't seem so far removed from us humanoid landlubbers at all.

However, these denizens of the deep also possess an incredible array of adaptations that make them very well suited to the bottomless, briny home to which they belong. Despite the dizzying amount of different species, all whales have a long, tapering shape ending in a powerful tail fluke that helps to provide streamlined thrust through the water. A thick layer of blubber (reaching up to 50 centimetres (20 inches) thick in bowhead whales!) keeps the heat in and provides fat stores to live off during tough times. A fantastic array of specialised dentition also allows for easy catching of prey, whatever that may be.

Whales also possess incredible means of communication. They are able to 'talk' to one another through eerie songs, as well as converse in a complex series of clicks and whistles. Body language also plays a part in cetacean communication, as whales spend plenty of time at the surface engaging in physical acts that can depict anything from warnings to mating displays, or simply jumping for the joy of being a whale.

"There are gentle giants that eat tiny plankton, and there are predators, who like their seal steak bleu"

Feeding

Gain an insight into the dining habits of whales, just don't invite one for supper...

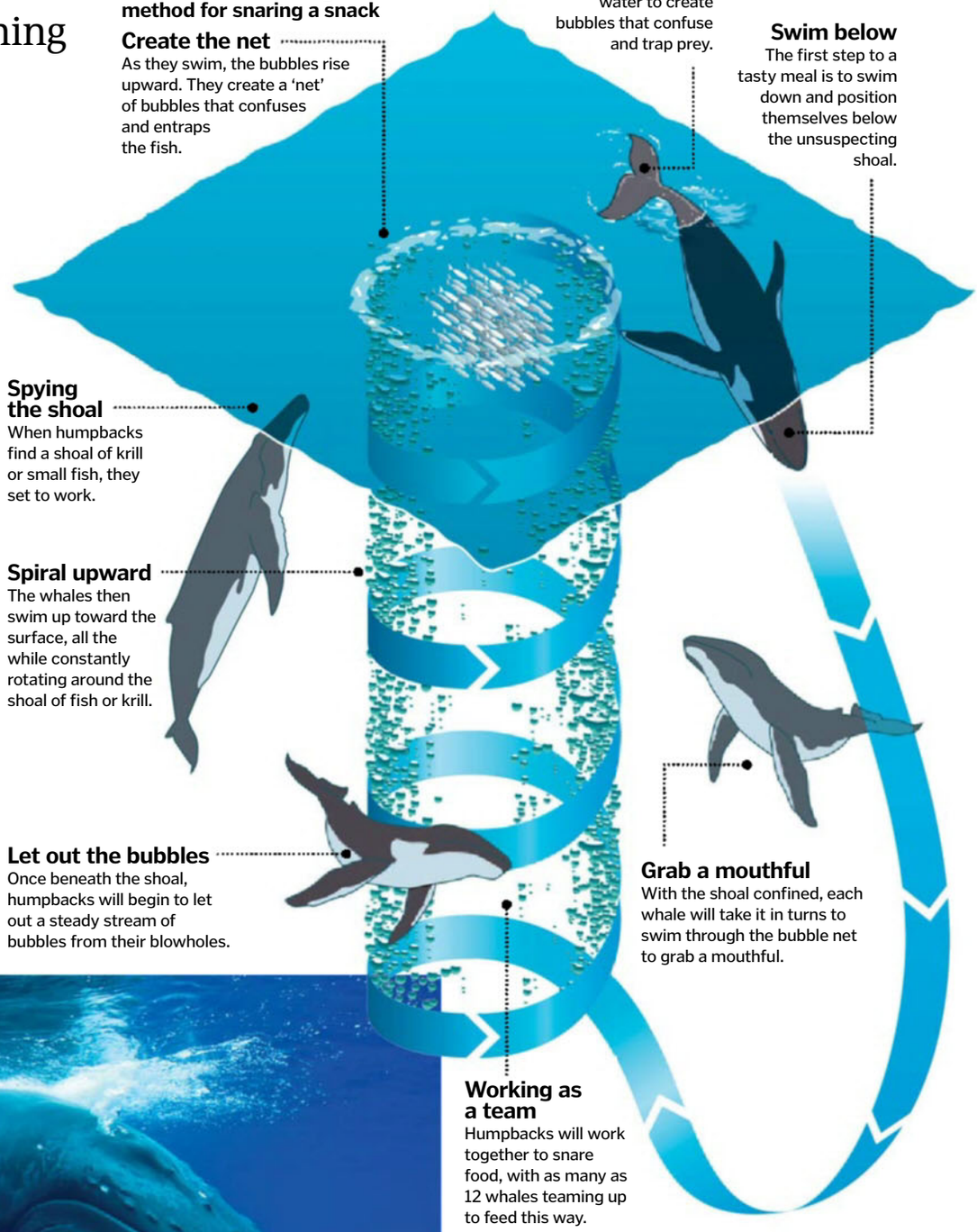
Whales have a vast array of requirements when it comes to feeding. There are the seemingly gentle giants such as the sei whale that filter large volumes of tiny animals from the water column. Then at the opposite end of the spectrum there are the quick and tricksy predators, such as the killer whales, who like their seal steak bleu.

All whales are carnivorous, but what a whale eats depends on its size, social structure, environment and life cycle. Each of these prey types has the key nutritional elements for the whale that eats it. The mighty blue whale can eat up to 4 tons of nutrient-rich krill per day, and at certain times of the year, such as the mating season for humpback whales, some species will stop eating completely.

With so many prey types available, hunting strategies have also evolved to suit the whale's dietary requirements. For example, a gray whale's favourite things to eat are invertebrates found in ocean sediment. These whales will scoop up giant mouthfuls of mud from the seafloor and filter out the tasty bits. Other whales will go to great lengths to secure themselves a meal, such as the sperm whale, which is reported to tussle with giant squid before tucking in.

Hunting with humpbacks

Discover their cunning method for snaring a snack



Create the net
As they swim, the bubbles rise upward. They create a 'net' of bubbles that confuses and entraps the fish.

Use the tail
Whales can also slap their tail flukes on the surface of the water to create bubbles that confuse and trap prey.

Swim below
The first step to a tasty meal is to swim down and position themselves below the unsuspecting shoal.

Spying the shoal
When humpbacks find a shoal of krill or small fish, they set to work.

Spiral upward
The whales then swim up toward the surface, all the while constantly rotating around the shoal of fish or krill.

Let out the bubbles
Once beneath the shoal, humpbacks will begin to let out a steady stream of bubbles from their blowholes.

Grab a mouthful
With the shoal confined, each whale will take it in turns to swim through the bubble net to grab a mouthful.

Working as a team
Humpbacks will work together to snare food, with as many as 12 whales teaming up to feed this way.

9,800km

LONGEST MAMMAL MIGRATION

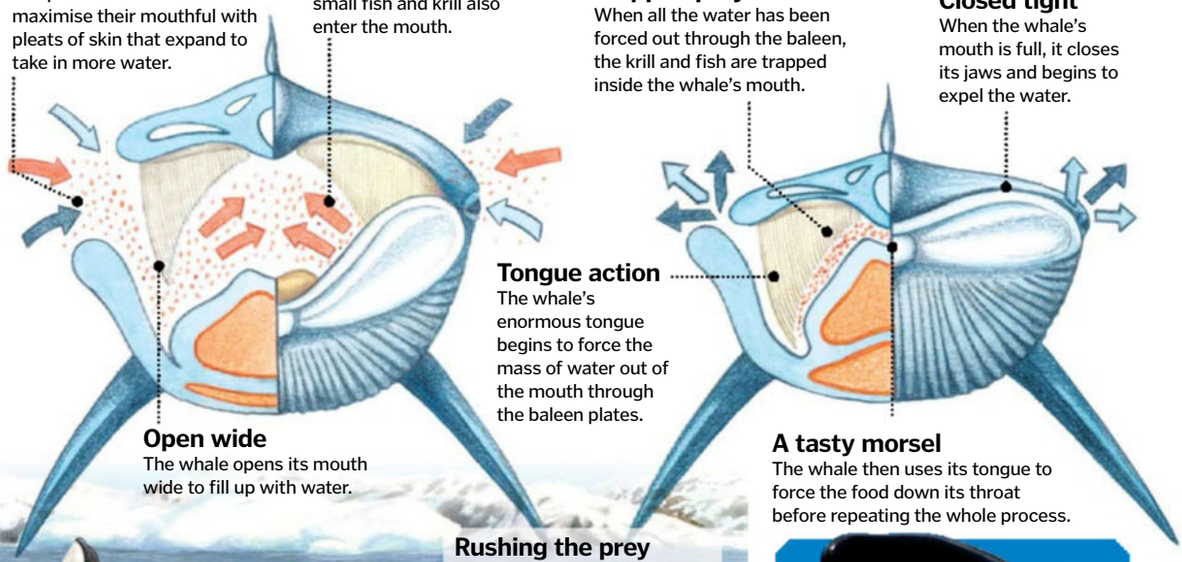
A female humpback whale, spotted in breeding grounds in Brazil, was then recognised in Madagascar two years later. Her journey was over 400km (249mi) further than the previous humpback migration record.

DID YOU KNOW? *You can determine the age of a baleen whale by looking a the ridges on its baleen, like rings on a tree stump*

Baleen vs Toothed

Baleen whales such as humpback, grey and blue whale species have a special type of mouth apparatus. Instead of teeth, they have plates of strong brush-like material that hang from their upper jaw. Made of keratin, the same stuff that makes up our own hair and fingernails, these large strands act as giant filters. When the whale takes a big gulp of water that contains food such as krill, it then closes its mouth and forces the water back out through the baleen plates. The baleen traps all of the tasty stuff inside, ensuring the whale gets a nutritious mouthful.

How baleen whales feed



Expandable mouth
Rorqual whales are able to maximise their mouthful with pleats of skin that expand to take in more water.

In goes the grub
Along with the water, small fish and krill also enter the mouth.

Open wide
The whale opens its mouth wide to fill up with water.

Tongue action
The whale's enormous tongue begins to force the mass of water out of the mouth through the baleen plates.

Trapped prey
When all the water has been forced out through the baleen, the krill and fish are trapped inside the whale's mouth.

Closed tight
When the whale's mouth is full, it closes its jaws and begins to expel the water.

A tasty morsel
The whale then uses its tongue to force the food down its throat before repeating the whole process.

How orcas hunt

Spy hopping
An orca's eyes are surprisingly effective out of water. These whales slip vertically out of the water to spy their prey.

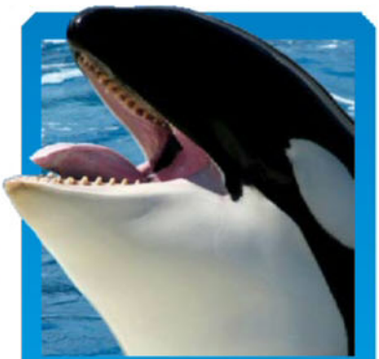
Rushing the prey
Whales charge toward the prey. This creates a wave and forces the seal onto shore or a berg to trap it.

Rocking the ice
Orca will nudge bergs, or even physically lift themselves out of the water to throw the prey off them.

Snaring the prey
Once one of these many tactics works, there will always be a hungry orca waiting with its jaws open...

Creating a wave
Using their tail flukes, whales will create a strong wave to flood over the berg and wash the prey into the water.

Using bubbles
Orca will also use bubbles from their blowholes to confuse and disorientate prey in the water.



Toothed whales, known as a group called the 'Odontoceti', tend to be smaller creatures in comparison to their enormous baleen-endowed cousins, but they include killer and sperm whales, as well as dolphin species. These whales can often be found in large social pods, and get their name from their full set of pearly whites. The number of gnashers differs greatly between individual species, but all teeth are uniform and are not replaced throughout the whale's lifetime.

While baleen whales eat small fish, toothed whales put their choppers to good use, and are able to eat much larger (and meatier) prey.

"Pods are usually made of whole families that develop strong bonds throughout their lifetimes"

Family life

As some of the most social oceanic creatures, life as a whale is a family affair

Although some whales prefer a solitary life, many species will live in large groups known as pods. These pods are usually made of whole families that develop strong bonds and can associate with each other throughout their lifetimes. The life span of a whale can vary, but species such as fin and gray whales can live for over 80 years.

With species such as killer whales, the familial pods are usually comprised of maternally related females. These groups can be regulated by a 'lead' female, sort of like a matriarch, and they can swim together as a unit, or spread out over a large expanse of ocean, keeping in contact using different methods of vocalization.

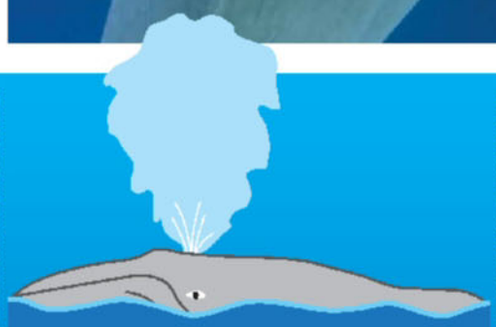
Whales will use a variety of clicks, groans, whistles and shrieks to get the message across. The low-frequency noises travel excellently in water, meaning that whales may keep in touch across extreme distances.

As well as the social aspect of pod life, living together adds an element of safety for the young, called calves. Whales give birth to live young, and the calf has to be ready to swim alongside its mother almost immediately after birth. Having a host of aunties, sisters and cousins around it for protection provides the young whale with the best possible start in life.

Staying with its family for many years, a baby beluga whale has an extremely strong bond with its mother

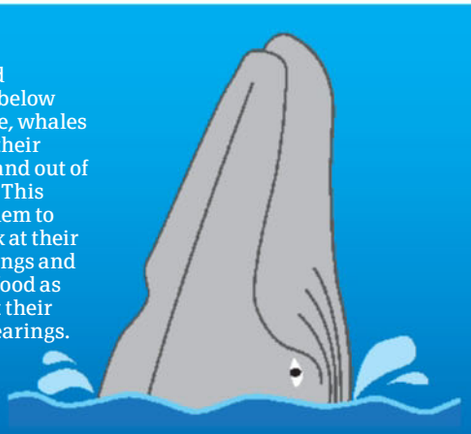
How to speak whale

The breach
This acrobatic display involves the whale launching its whole body skyward (powered by a few pumps of its tail), sailing out of the water and then landing back on the surface with an almighty slap.



Blow
When a whale surfaces to breathe, on average every 15 to 30 minutes for adults (three to five minutes for calves), it will let out a colossal spray of water and air from its blowhole.

Spy hop
Positioned vertically below the surface, whales will slide their heads up and out of the water. This enables them to take a look at their surroundings and check for food as well as get their general bearings.



STRANGE BUT TRUE
WHALE RESTED

How do sperm whales sleep?
A In warm shallow water
B Vertically in the water
C In whale-sized hammocks

Answer:
In 2008, scientists came across an eerie sight of a pod of sperm whales hanging vertically in the water with their heads just below the surface. They were even able to nudge one! The whales were grabbing forty winks, and solved the mystery of how they sleep.

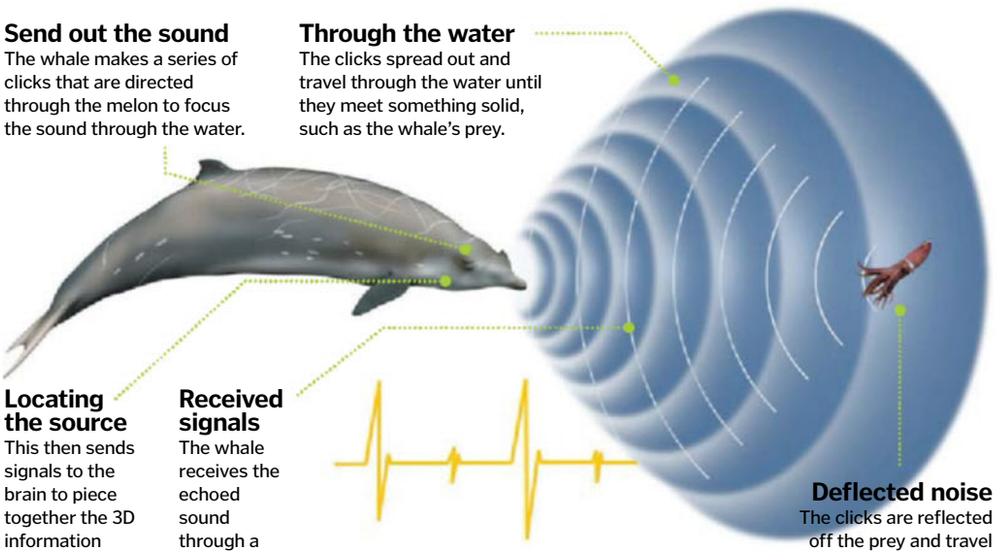
DID YOU KNOW? *The amount of squid eaten by sperm whales every year is estimated to be over 100 million tons*

Whales are able to communicate over incredible distances – no 4G needed

Echolocation

Redefining the meaning of long-distance calls…

This amazing sense uses sound waves and echoes to help the whales determine the location of things like prey, predators and undersea geography. The melon, an organ found in the whale's forehead, plays a part in echolocation. It focuses the sound waves made by the whale, in a similar way to how a camera lens focuses light.



Send out the sound
The whale makes a series of clicks that are directed through the melon to focus the sound through the water.

Through the water
The clicks spread out and travel through the water until they meet something solid, such as the whale's prey.

Locating the source
This then sends signals to the brain to piece together the 3D information about what is ahead of it.

Received signals
The whale receives the echoed sound through a pad of fat in its jaw.

Deflected noise
The clicks are reflected off the prey and travel back through the water toward the whale.

Migration: Expert Q&A

We caught up with Regina Asmutis-Silvia, executive director of North American Whale and Dolphin Conservation to chat about the hows, whys and wheres of whale migration.

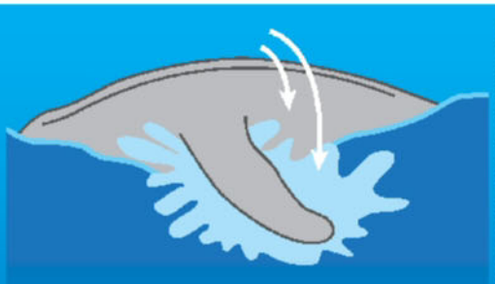
What are the main types of whales that migrate yearly?
Most baleen whales migrate seasonally, feeding in the colder waters during the spring, summer and autumn, and moving to warmer waters for breeding and mating in the winter. That means they migrate twice a year.

Which whale goes the furthest?
Humpback whales currently hold the mammal migration record. The longest recorded migration for humpback whales is over a 16,000-kilometre (10,000-mile) round trip!

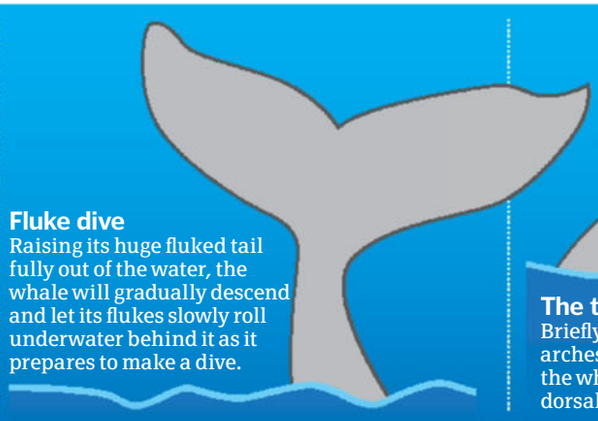
Why do they do it?
Colder waters hold more oxygen and tend to be more productive, providing an abundant food supply for large whales. However, in the winter, these waters do not hold as much prey, so some researchers believe whales migrate to warmer waters for breeding to save energy.
Others speculate that calving in the coastal coral beds of the tropics may be safer for newborn calves to avoid predators.

How do they know where to go and how do they navigate?
The theory is that humpbacks use the Earth's magnetic field and the direction of the Sun. Humpback whales have magnetite (iron oxide crystals) in their brains that may help them align to the magnetic fields in the Earth's surface. Other researchers hypothesise that the whales may use the Moon and stars as navigational aids. Long-distance songs may be a fourth component in helping the humpback navigate.

WDC, Whale and Dolphin Conservation is dedicated to the conservation and protection of whales and dolphins. For more information, visit ***www.whales.org****.*



Fin slap
Possibly as a way of showing off during breeding season, whales will align their pectoral fins to the surface and splash them down hard, moving one or both fins simultaneously.



Fluke dive
Raising its huge fluked tail fully out of the water, the whale will gradually descend and let its flukes slowly roll underwater behind it as it prepares to make a dive.

The tell
Briefly breaching the surface, as it arches its back before making a dive the whale will show its back hump or dorsal fin above the water.

"Further erosion and collapse transforms these cracks into networks of tunnels and caves"

Cave creation

How do huge parts of the Earth get hollowed out?

Caves can form anywhere whether it's in the surface of the Earth, underwater or even inside mountains. In fact, any lump of rock has the potential to turn into a cave because they're created by erosion, which can happen by a number of means.

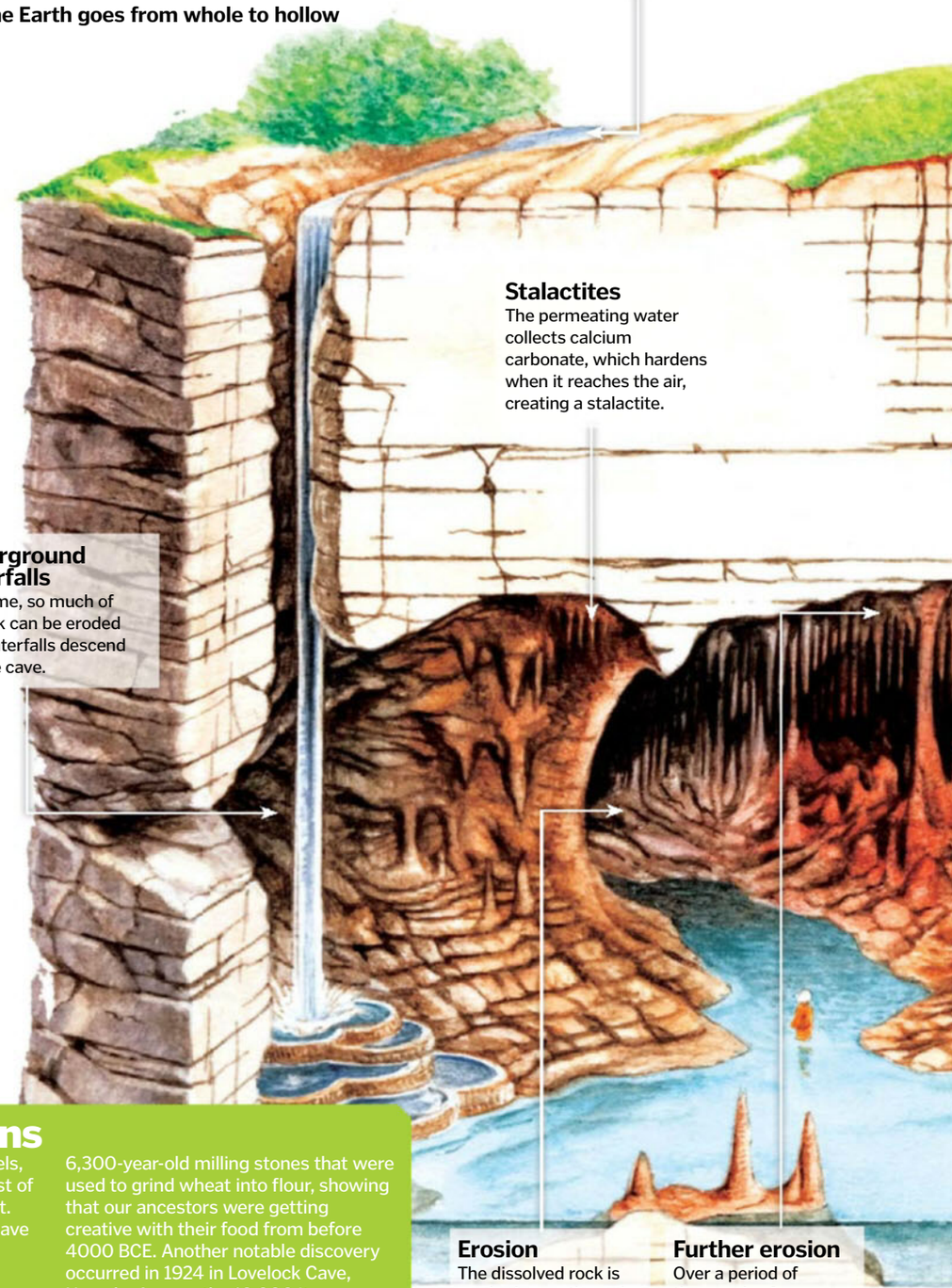
The most common kind of cave is called a solution cave. These tend to be made of rocks such as limestone or gypsum, as they dissolve faster in water than other kinds of rock. Water falling as rain collects carbon dioxide from the atmosphere before descending through the ground. The carbon dioxide mixed with rainwater can form carbonic acid, which is a key ingredient in dissolving the rock, especially in places where there is an existing fissure. Further erosion and collapse transforms these cracks into networks of tunnels and caves. The water will either stay in the base of the cave once it reaches rock that it can't dissolve, or flows out through a hole to begin the whole process again.

Some of the most incredible formations in cave structures are stalactites and stalagmites. Stalactites are the pointy shards that descend from the roof of a cave. These are created when the dripping rainwater collects calcium carbonate on its way through the rock. Once it reaches the open space the calcium carbonate solidifies. This builds up as water drips along the stalactite before hardening. Stalagmites are made of calcium carbonate too, but build from the base of the cave upward if the water has dripped down before becoming solid.

Underwater and overground caves are formed in similar ways. Rock is repeatedly attacked by a force of nature, such as ocean tides, winds or sand. This bombardment wears away at the rock, creating a dent that gets steadily bigger until a cave is formed.

Inside a cave

How the Earth goes from whole to hollow



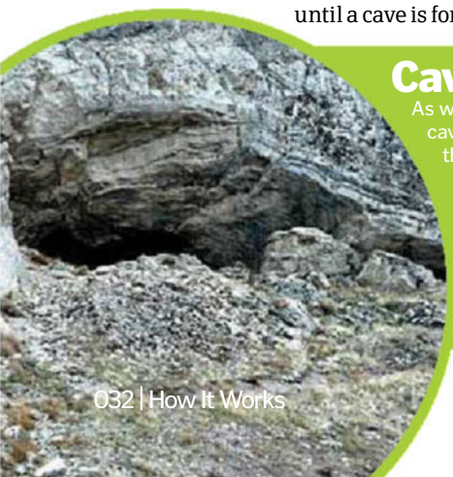
Rainfall
As rain falls it collects carbon dioxide and forms carbonic acid, which dissolves the rock, especially in places with existing cracks.

Stalactites
The permeating water collects calcium carbonate, which hardens when it reaches the air, creating a stalactite.

Underground waterfalls
Over time, so much of the rock can be eroded that waterfalls descend into the cave.

Erosion
The dissolved rock is washed away through underground streams, leaving larger and larger spaces.

Further erosion
Over a period of thousands of years the continued erosion creates enormous underground caves.



Cave revelations

As well as being natural marvels, caves can tell us a whole host of things about life in the past. Archaeologists in China have unearthed evidence of humans making fire in caves as far back as 400,000 years ago. Meanwhile, the Cowboy Caves of Utah revealed 6,300-year-old milling stones that were used to grind wheat into flour, showing that our ancestors were getting creative with their food from before 4000 BCE. Another notable discovery occurred in 1924 in Lovelock Cave, Nevada. Among the 10,000 items found were 'duck decoys' – devices used to lure ducks toward hunters who would catch them for food!

What is inside a Lanzarote lava cave?

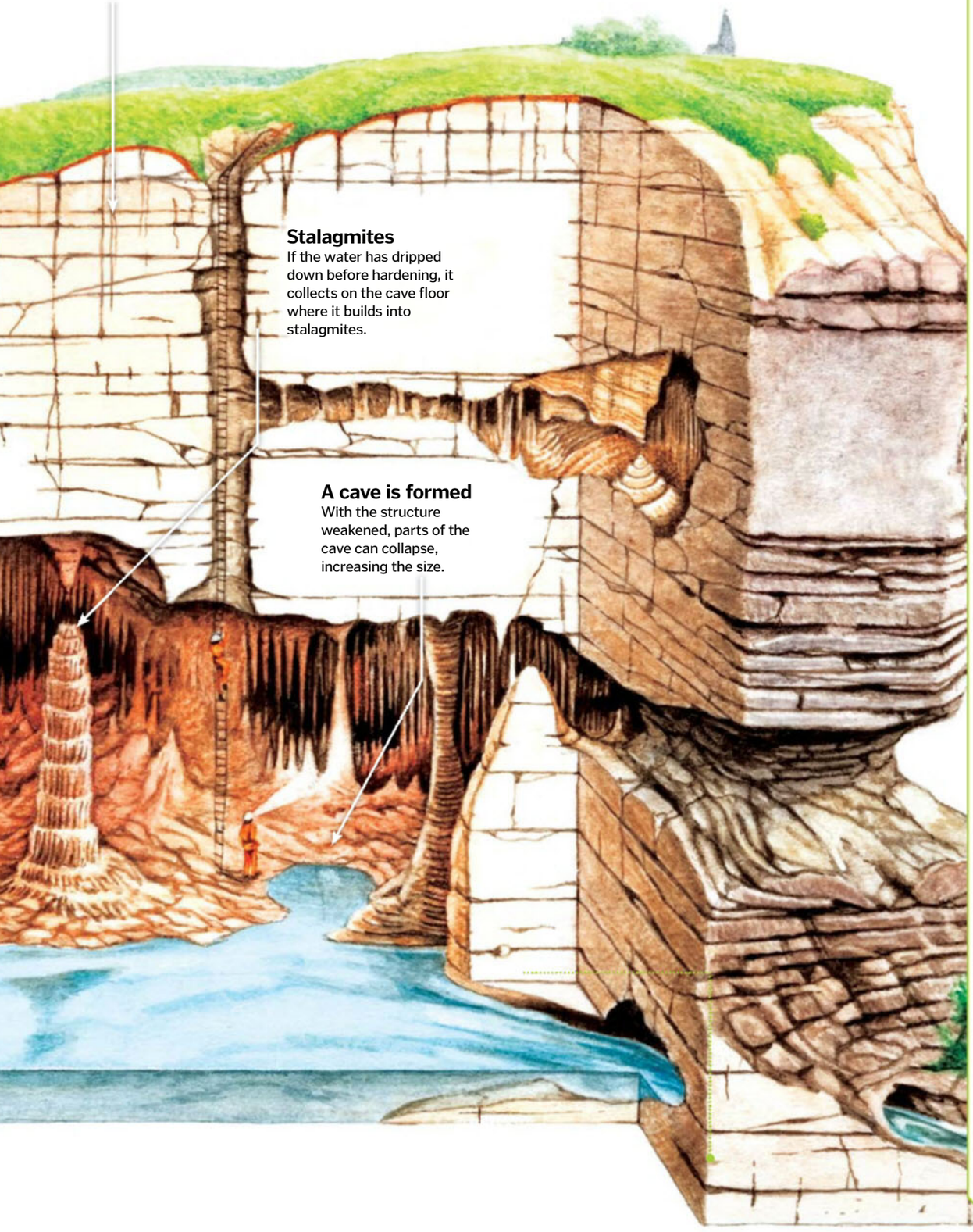
A House **B** Restaurant **C** Bouncy castle

Answer:
César Manrique, Lanzarote's most famous artist, lived inside a system of volcanic bubbles that were formed by a 1730 volcanic eruption. It was his studio for 24 years before housing the César Manrique Foundation, an organisation that aims to promote the arts.

DID YOU KNOW? *Cavemen rarely lived in caves. They would use them for shelter but built huts out of wood, mud and animal skins*

"Some of the most incredible formations in cave structures are stalactites and stalagmites"

Rocks
Most caves are made from rocks such as limestone that are easily dissolved.



Stalagmites
If the water has dripped down before hardening, it collects on the cave floor where it builds into stalagmites.

A cave is formed
With the structure weakened, parts of the cave can collapse, increasing the size.

Four main types of cave

Solution cave
This is the most common kind of cave in the world. Formed from water moving through carbonate or sulphate rock, these types of cave grow to form some of the largest caverns on Earth.

Lava cave
Created when lava is flowing along a path and part of it cools and hardens. This leaves the still-molten lava inside to continue flowing, ultimately resulting in hollow lava tubes.

Glacier cave
The most common cause is melt water running through, or under, the glacier. This widens crevices and carves out chutes, which will then increase in size during the summer months.

Sea cave
Underwater and coastal rocks are constantly battered by waves. This action erodes the weaker parts of the rock. Some of these get flooded and become underwater cave systems.

"If you were to completely surround an egg with your hand and squeeze it, you wouldn't be able to break it"

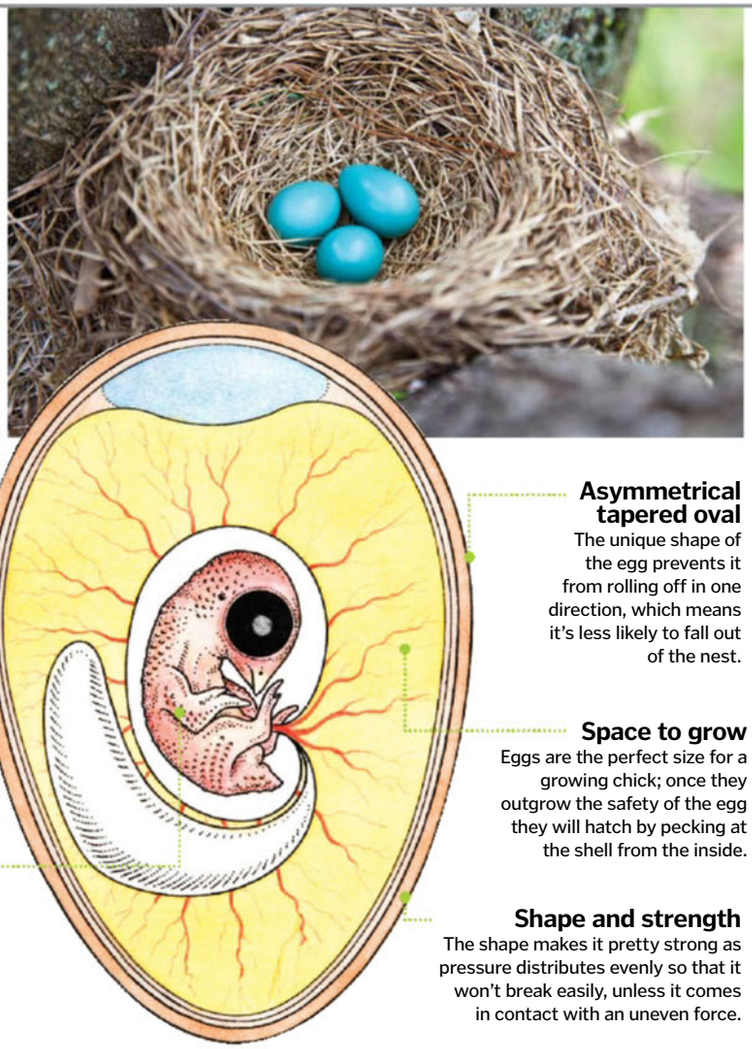
Egg structure

Discover how the shape of an egg keeps it from cracking under pressure

Contrary to their delicate appearance, bird eggs are in fact surprisingly resilient, which is all thanks to their unique shape and structure. The asymmetrical tapered oval shape of an egg actually makes it extremely strong under pressure.

In fact, if you were to completely surround an egg with your hand and squeeze it hard, you wouldn't be able to break it. It may sound unbelievable, but it's actually true. The secret behind it is all down to the curved shape of the egg, which essentially distributes the pressure evenly. Of course, if you were to strike an egg with an uneven force, it would break easily without question.

The shape of a bird egg is down to evolution. It makes the laying process much easier for the female bird and also prevents the egg from rolling easily out of the nest. You'll notice this is you've ever nudged an egg on a flat surface as they will sweep round in a circle as opposed to rolling off in a straight line. Their shape also enables multiple eggs to pack close together in the nest for extra warmth.



Tough shell
Eggshells are made of calcium carbonate and can be pretty tough. They also have microscopic pores, which help supply oxygen to the growing embryo.

Developing chick
The embryo inside has everything it needs to develop. An air sac provides oxygen whilst the egg white, also known as albumin, provides food.

Asymmetrical tapered oval
The unique shape of the egg prevents it from rolling off in one direction, which means it's less likely to fall out of the nest.

Space to grow
Eggs are the perfect size for a growing chick; once they outgrow the safety of the egg they will hatch by pecking at the shell from the inside.

Shape and strength
The shape makes it pretty strong as pressure distributes evenly so that it won't break easily, unless it comes in contact with an uneven force.

How is dew formed?

Discover why these sparkling drops appear on the ground

Glinting dewdrops are a familiar sight for early risers in the morning, but dew is not a sign of overnight rain. These picturesque water droplets are actually formed when water vapour in the air comes into direct contact with cold surfaces. This is why dew usually forms overnight, as surfaces on the ground will cool due to a loss of infrared radiation from the Sun. You're more likely to notice dew after a calm, cloudless night too, as cloudy skies help insulate the Earth and enable surfaces, where dew would otherwise form, to retain some level of heat.

Dew usually forms overnight when the ground cools

5 TOP FACTS
HIBERNATION

Cold-blooded animals
1 Some reptile species hibernate during the winter and will only wake when temperatures rise. The wood frog's body temperature can drop to a freezing -6°C (21°F) during hibernation.

Length of hibernation
2 The number of months an animal hibernates varies depending on the species and their environment; some will hibernate for five to eight months.

Brown fat
3 Most mammals that hibernate have a layer of brown fat that isn't burned for energy when they're in a sleep-like state. It actually helps to generate some heat to keep them warm.

Surprising hibernators
4 Some species of fish and even birds are known to hibernate, or at least enter a similar state of reduced activity. The fat-tailed dwarf lemur is the only known primate that can hibernate.

Waking early
5 Waking a hibernating animal during winter can kill it, as rousing from hibernation and re-entering it takes up a lot of energy, which means it winter reserves will deplete quicker.

DID YOU KNOW? *Alpine marmots are profound hibernators. They can remain in a sleep-like state for up to 200 days!*

Hibernation

Discover why animals go without food or water for months at a time

Winter in the wild can be extreme, low temperatures and a scarce amount of food make it difficult for many animals to survive. Some will migrate south during the winter months, but certain species of mammals, rodents and reptiles simply bed down and hibernate until spring.

Hibernation is an extremely effective survival strategy that suspends the animal's body functions and metabolism so it can preserve energy. This state of suspended animation will allow its body temperature to drop and the breathing and heart rate slow right down. In fact, a chipmunk's heart rate can drop from a frantic 200 to just five beats per minute during hibernation, and fat-tailed dwarf lemurs will only take a breath once every 20 minutes!

Hibernation is triggered by seasonal changes within the animal's habitat. Hibernating species are sensitive to alterations in their environment and can therefore predict the onset of winter. They also produce a hormone called hibernation-specific protein, which prompts the physiological changes needed to conserve energy while in a sleep-like state.

Prior to hibernating, many animals will eat excessively over the summer months in order to build up a reserve of fat. For instance, bears can consume up to 20,000 calories a day. Some species that hibernate even store imperishable food within their den and wake for short periods during hibernation to eat.

Once spring arrives and the temperatures begin to climb once again, the hibernating animal will start to rouse. The length of hibernation varies depending on the species, individual animals and even the weather patterns that year.

What's the difference between hibernation and sleep?

Hibernation is a much longer process than sleep, and the animal will go through physiological changes that, although similar to those that occur during sleep, are much more extreme. For instance, warm-blooded animals that hibernate turn almost cold-blooded as their body temperature can drop significantly. Their metabolism, breathing and heart rate also slow down dramatically, and they can remain motionless in a coma-like state for days at a time. Waking from hibernation is also a much longer, gradual process when compared to waking from sleep.

Sleep itself is also considered more of a mental process, as changes occur to brain activity. On the other hand, hibernating animals have shown brain waves that resemble wakeful brain activity, although they are suppressed. Once an animal wakes from hibernation they will still require a lot of sleep in order to recuperate from the long slumber. In fact, it can take weeks for some animals to recover from several months of hibernation.

Anatomy of a bear in hibernation

A hibernating bear's body is anything but idle – here are some of its key functions

Burning reserves
A hibernating bear will use up to 4,000 calories a day. Their body fat breaks down to provide this energy in addition to water.

Balancing hormones
Glands within the body delicately balance an animal's hormone levels during hibernation, which affect insulin levels, melatonin and the thyroid and pituitary glands.

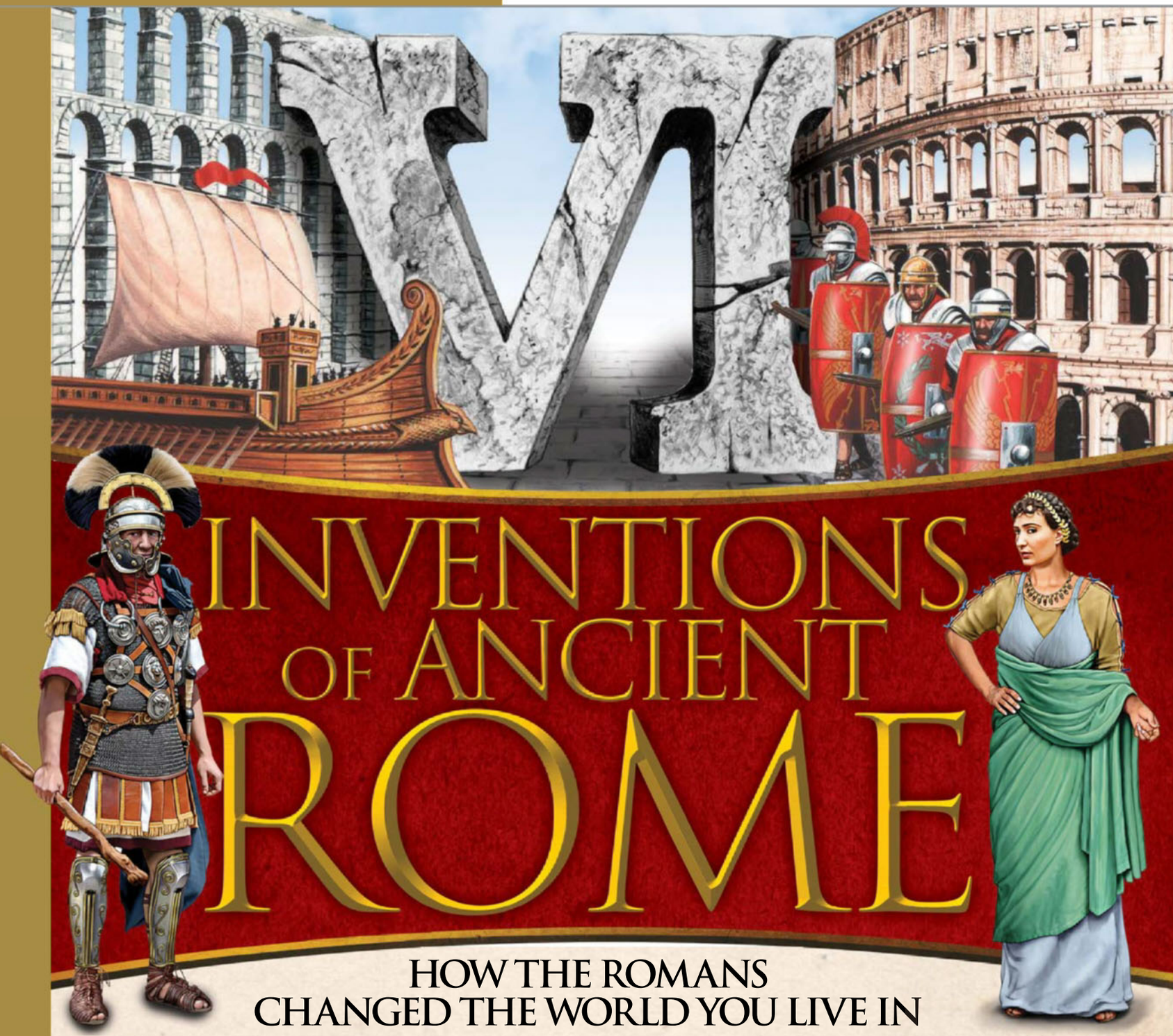
Healing process
During hibernation a black bear's wounds will heal with no infection or scarring.

Heat rate
A bear's heart will slow to less than 20 beats per minute when hibernating.

Absorbing proteins
Bears will not wake to urinate or defecate during hibernation; they actually reabsorb urea in the form of proteins.

New skin
Bears' paw pads will peel away during the winter and be replaced by new healthy tissue in the spring.

Staying warm
Unlike other hibernating mammals, bears' bodies stay relatively warm. Their body temperature only drops by around 5.5°C (10°F), but their metabolism slows by 75 per cent.



INVENTIONS OF ANCIENT ROME

HOW THE ROMANS CHANGED THE WORLD YOU LIVE IN

Perhaps the greatest of all the ancient civilisations, the Roman Empire represented the age of classical antiquity and helped create the world we live in today. The massive engineering projects that were undertaken and the advances in medicine and society ensure Roman influence can still be felt now. For example, concrete and cement were first popularised in Ancient Rome, as was a type of central heating known as a hypocaust.

One of the most remarkable traits of all though, was the ability for the Romans to work all their schemes and inventions into fully functioning cities within an extensive empire. Rome itself was a bustling metropolis that no other civilisation matched in prosperity and size for centuries afterward. Nowhere else in the ancient world had grand shopping centres like Trajan's Market, specialised landfill sites such as Monte Testaccio or extensive sewer networks like the Cloaca Maxima. They were also famously proficient at town planning and building large structures.

Home life was revolutionised under the Romans. Also, as is well known, the army was an all-conquering juggernaut that took the old world by storm. To commemorate their affect on modern society and technology, **How It Works** discovers just how innovative and ground-breaking this civilisation really was.

Carthage
The centre of the defeated Carthaginian Empire, Rome made Carthage one of its main satellites with as many as 500,000 people.

Alexandria
The Egyptian city became prosperous in the Ptolemaic dynasty and by the time of Roman conquest had 500,000 to 750,000 inhabitants.

Rome
With an estimated population of 1 million and the home of the emperor, Rome was the empire's main urban metropolis.

DID YOU KNOW? *Lugo in Spain is now the only city in Europe to still be surrounded by intact Roman walls*

Engineering in Roman home life

The technology inside a Roman house

The citizens of Rome had to be properly housed to ensure that the vast urban sprawl could operate as an organised society. Prior to the Romans, impressive structures were built by the Egyptians and the Greeks but never on the scale of the Roman Empire with its extensive housing projects.

Roman building techniques owed a lot to Greek and Etruscan influences. Houses were one or two storeys high and included lots of different sections. Ideally adapted to the Mediterranean heat, the typical Roman house often had no windows (glass was rarely used), instead fitted with an atrium to act as an open-air courtyard in the middle of the building. Life in a house was boosted by a fully functioning public welfare system that provided grain to 300,000 of Rome's families every year. If you wanted some retail therapy, Trajan's Market had over one hundred tabernae (shops) selling a variety of goods.

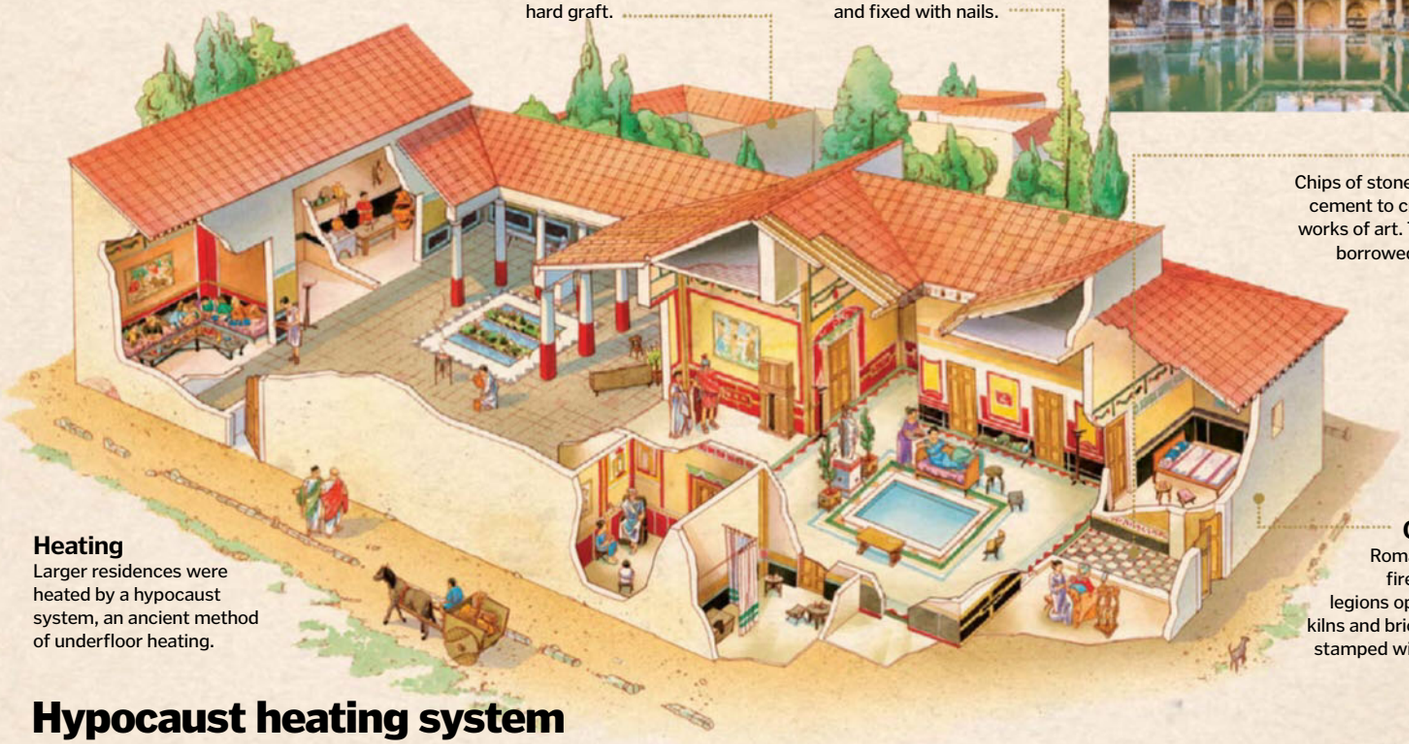
Not every citizen was lucky or rich enough to own a house. Lower classes were put into one of Rome's many 'insulae' apartment buildings and there are believed to have been over 40,000 of these in the city. In fact, these apartments outnumbered family houses by 20 to one!

The Roman residence

More than just a roof above your head, the Roman house was quite complex

Building blocks
The Romans used pulleys and levers to shift large building blocks. Slaves carried out the hard graft.

Roof tiles
A stonesman would carve thin tiles from stone. These were laid on top of wooden beams and fixed with nails.

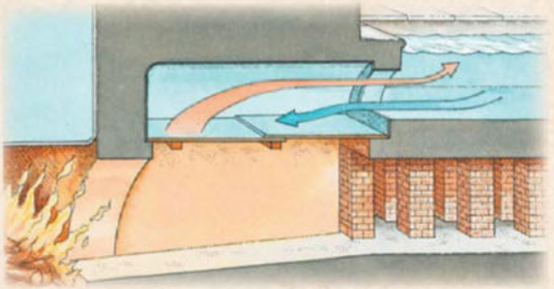


Mosaics
Chips of stone were laid into cement to create beautiful works of art. This technique borrowed from Greece.

Heating
Larger residences were heated by a hypocaust system, an ancient method of underfloor heating.

Clay bricks
Roman bricks were fired clay. Roman legions operated mobile kilns and bricks were often stamped with the mark of the legion.

Hypocaust heating system



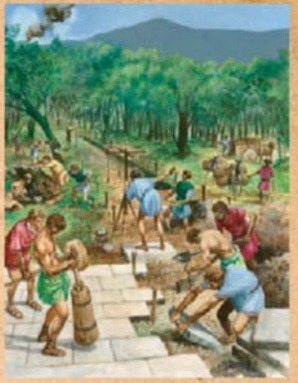
Convection currents
Underneath a raised floor, vents allowed heated air to travel freely and used convection currents to heat the tiles above. The warm air came from a wood-burning furnace.

Running the hypocaust
Slaves kept the system running by keeping the flame alight. It is still unknown how well the convection currents worked and whether some rooms got too hot because of the system.

Disadvantages
The hypocaust was reserved only for the wealthiest villas and large bathhouses. Also, the burning of wood produced toxic carbon monoxide fumes.

Roman roads

Roman roads interlinked cities and towns and allowed rapid military and administrative communications. Construction began with a trench, which was filled with a base of stones and rocks. These were packed together tightly, usually with cement, to create a firm foundation for armies to march on and chariots to ride across. Large paving stones were used on the surface. These were placed and fitted by hand along with channels on the side of the road that allowed water to run off into surrounding fields. In the UK, roads such as the A1 and A5 owe their origins to the Roman conquest of Britain.



"Where possible, the majority of an aqueduct was built underground to protect it from enemies"

Aqueduct engineering

How the Romans built their immense water-management network

Aqueducts weren't invented by Romans but were popularised by them. These structures were the life stream of a city. 1,300 drinking fountains and 144 public toilets were located in Rome and they were all fed by the complex system of aqueducts, which brought in fresh drinking water from rural areas. The system was accompanied by an elaborate network of sewers.

Rome's main sewer was known as Cloaca Maxima and carried dirty water out of the city and into the River Tiber. The first-ever aqueduct was the Aqua Appia, built in 312 BCE. It helped relieve the demand for water in a rapidly growing Rome. Where possible, the majority of an aqueduct was built underground to protect it from enemies. The iconic raised arches were only required when the structures neared a city or needed to cross a ravine.

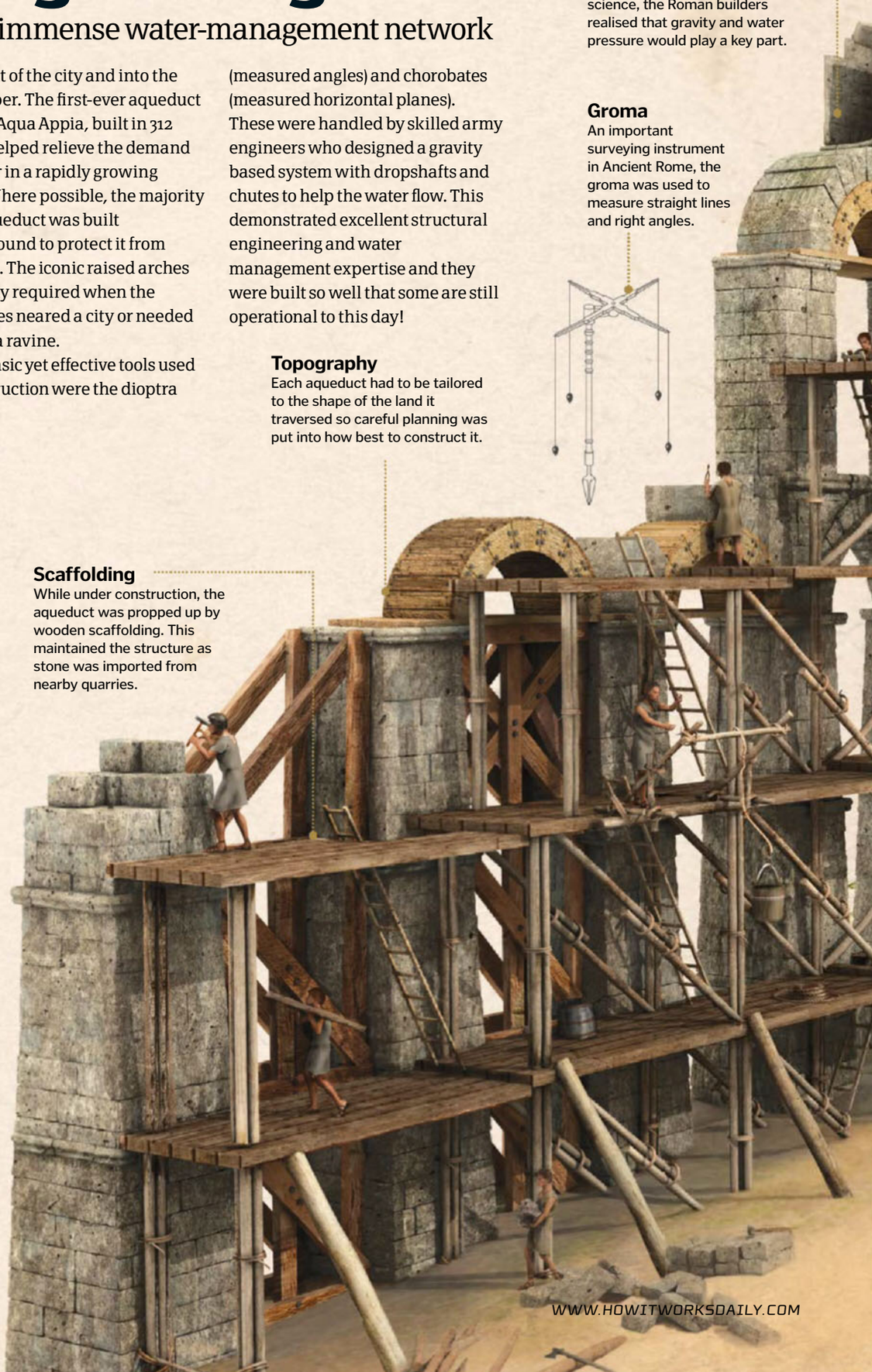
The basic yet effective tools used in construction were the dioptra (measured angles) and chorobates (measured horizontal planes). These were handled by skilled army engineers who designed a gravity based system with dropshafts and chutes to help the water flow. This demonstrated excellent structural engineering and water management expertise and they were built so well that some are still operational to this day!

1 Building materials
Aqueducts were primarily constructed out of limestone that was mined from neighbouring quarries. These slabs of rock were bound together by Roman concrete and cement, which was made out of durable and waterproof volcanic sand called pozzolana.

2 Planning
The building of aqueducts was often financed by the emperors themselves, so meticulous planning was put into the operation. The land needed to be surveyed by engineers to make sure it was fit for construction.

3 Construction techniques
The reinforced Roman concrete arch was an essential part of the aqueduct as it could hold the pressure and weight of the water after the wooden construction supports had been removed. Pulleys, wedges and screws were used as lifting apparatus.

4 Design and uses
The water was carried a great distance from spring to urban area and was then held in cisterns in the city and onto a network of pipes to each individual building. Aqueducts also aided a town's sewer system and protected against fires.



Hydraulics
Despite having a limited knowledge of construction science, the Roman builders realised that gravity and water pressure would play a key part.

Groma
An important surveying instrument in Ancient Rome, the groma was used to measure straight lines and right angles.

Topography
Each aqueduct had to be tailored to the shape of the land it traversed so careful planning was put into how best to construct it.

Scaffolding
While under construction, the aqueduct was propped up by wooden scaffolding. This maintained the structure as stone was imported from nearby quarries.

1MILLION

ROME'S LONG-STANDING RECORD

Rome's population peaked at 1 million people when the empire was at the height of its powers. This number wasn't topped in Europe for nearly 2,000 years, until London began to prosper in the Industrial Revolution.

DID YOU KNOW? *Rome's aqueducts provided up to 1,000 litres (264 gallons) of water for every person in the city*

Covering
On the overground parts of an aqueduct, a roof called a 'specus' was sometimes used to protect the water from the elements, keeping it fresh and clean.

Arches
Arches were a popular feature of Roman architecture. Strong and versatile, an aqueduct would have been much less effective without them.

Flowing far

Many claim that aqueducts were one of the best Roman developments. Frequent throughout the Roman world, their effective and modern system was lost after the fall of the empire and never recovered until much, much later in human history. A lot of these structures were actually underground, but they are most fondly remembered for their overground segments with their iconic vaulted arches that were essential in their construction. As techniques improved, aqueducts were also used to supply out-of-town factories and mines with water. The longest aqueduct in Rome was the Aqua Marcia at 91 kilometres (57 miles) from source to city, but even longer systems were built across the empire.

Roman newspapers

All citizens in Rome were kept up-to-date with two daily newspapers. The *Acta Senatus* made sure the public was up to speed with what was going on in the Senate while the *Acta Diurna* was a daily gazette based on Roman news and weather. Both publications were handwritten so their circulation wasn't exceedingly high, but the *Acta Diurna* lasted two centuries of service. The *Senatus* wasn't so lucky as several emperors forbade its publication and preferred to keep Senate minutes private. They were also pioneers of the postal service. The Cursus Publicus was a state-run courier system that delivered messages throughout the Roman Empire.

"Rome itself was a bustling metropolis that no other civilisation matched in prosperity and size for centuries"

Buildings

The biggest cities were home to the biggest buildings

In its prime Rome was one of the, if not the most, technologically advanced cities in the world. Containing huge, expansive buildings, revolutionary architecture and a housed, fed and watered population within its walls, the vast empire's capital in Rome was well ahead of its time.

The Colosseum became the cultural centre of Rome after its construction in 80 CE, but the capital also contained one of the largest sports stadiums of all time, the Circus Maximus, as well as other examples of stunning engineering, such as the Pantheon, the Arch of Septimius Severus and the Theatre of Pompey.

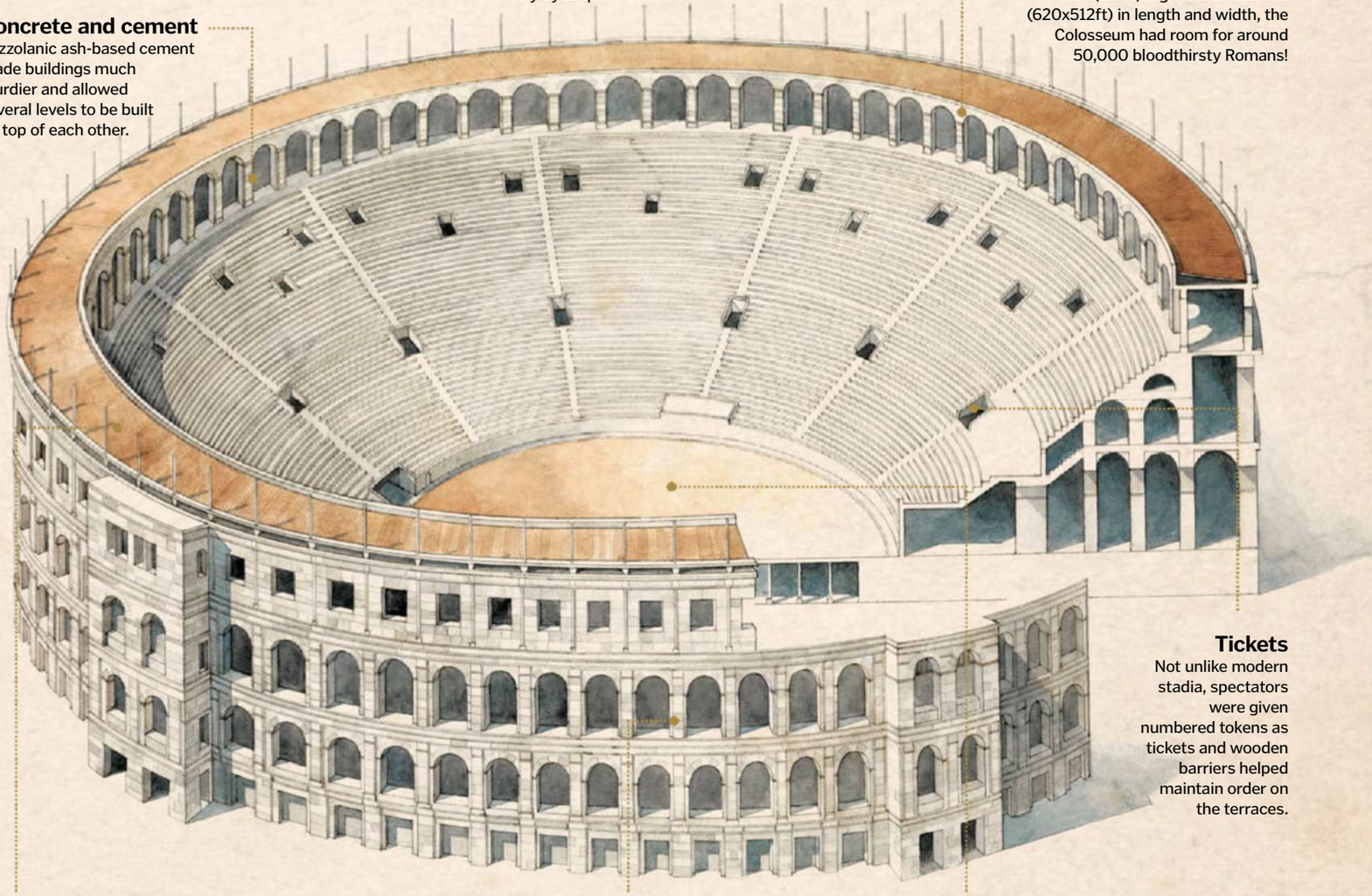
The Colosseum

How the centrepiece of the empire and its architecture was built

Concrete and cement
Pozzolanic ash-based cement made buildings much sturdier and allowed several levels to be built on top of each other.

All in a name
The name 'Colosseum' comes from the word 'colossus' which was the name of giant statues erected in the city by Emperor Nero.

Dimensions
48m (157ft) high and 189x156m (620x512ft) in length and width, the Colosseum had room for around 50,000 bloodthirsty Romans!



Tickets
Not unlike modern stadia, spectators were given numbered tokens as tickets and wooden barriers helped maintain order on the terraces.

Velarium
All the spectators in the Colosseum were protected from the hot Mediterranean sun by an awning called the velarium.

Construction
The Colosseum's outer wall was made from 100,000m^3 (3.53mn ft^3) of limestone held together by 300 tons of iron clamps.

Arches
80 concrete arches meant the Colosseum had an extremely durable design, which has allowed it to stand for nearly 2,000 years!

Underground labyrinth
Underneath the Colosseum was a system of tunnels that elevated cages into the arena using a slave-run pulley system.

5 TOP FACTS
ROMAN MILITARY

Organisation
1 80 legionnaires were in a century. Together, six centuries made a cohort of 480 men. A legion had ten cohorts and the entire army contained 30 legions, a total of around 150,000 soldiers.

Training
2 Training lasted four months and consisted of marching, formation and weapons training. Recruits also learned to swim, ride a horse and use a bow and a sling.

Pay
3 A legionnaire would earn a basic 225 denarii for a year's service. Out of this wage packet were deductions for equipment, food and even a regiment savings bank.

Army oath
4 Each soldier would swear a 'sacrementum' when they began their service, pledging their allegiance to the emperor and vow never to abandon comrades or desert a battle.

Clothing and armour
5 Armour was light but sturdy. The helmets and armour could repel projectiles while the military-issue tunic was comfortable enough to wear on long marches.

DID YOU KNOW? *Soldiers had to be able to march 32km (20mi) in five hours while carrying around 20.5kg (45lb) of equipment*

Military
Ingenious conquerors

On both land and sea, the Roman Empire dominated warfare for centuries, invading large portions of Europe and making significant inroads into Africa and Asia Minor. The Romans outwitted their opponents using expert battle tactics and perfectly engineered weapons and armour. Soldiers were divided into legions that served different territories and swore an oath of loyalty to the centurions. One of the main reasons why the Romans consistently beat their enemies (and what links them to today's military) is the fact that the army was a professional conscripted force. A full-time operation, a soldier was one of the highest-paid and most-respected occupations in the empire.

THE WAR AT SEA

On the high seas of the Mediterranean, the Romans enjoyed even more dominance than on land. Using triremes and galleys propelled by teams of over 100 men, ships attacked either by ramming the opposition or boarding their ships. Owing a lot of their strategies to reverse-engineering methods learnt from the Greeks and Carthaginians, maritime superiority was essential for victory in the Punic Wars and Egypt campaigns. The senior arm of the Roman navy was known as the Classis Misenensis and except for internal civil wars, achieved total marine dominance for Rome after the Punic Wars.

Romans on the battlefield

What a battle between the Empire and a barbarian horde would have looked like

Formation
Legionnaires would form a defensive front using their rectangle scutum shields, which was a progression on the Greek phalanx formation.

Centurions
A centurion usually commanded a unit of 80 men and was in charge of their training and discipline after rising through the ranks.

Cavalry
Roman cavalry riders supported the legionnaires by attacking an army's flanks. They could also chase down any enemies that tried to escape.

Legionnaires
The legion was the main unit of the army and applicants were required to be Roman citizens between the ages of 17 and 45.

Ranged warfare
The pilum and verutum were spears used for long distance attacks to unsettle the enemy ranks before a charge.

Auxiliaries
Auxiliaries (non-citizen soldiers) formed the rest of the Empire's militia and could only be granted citizenship after 25 years' service.

Discipline
The strict Roman ranks were extremely effective against the barbarian hordes, who had no effective response to the Testudo (tortoise) formation.

Close-quarters combat
Either a gladius or pugio was used in tight hand-to-hand combat when the two forces engaged in a close proximity.

"Completed in 1798, it became an instant landmark, towering over the low-lying rest of the city"

Massachusetts State House

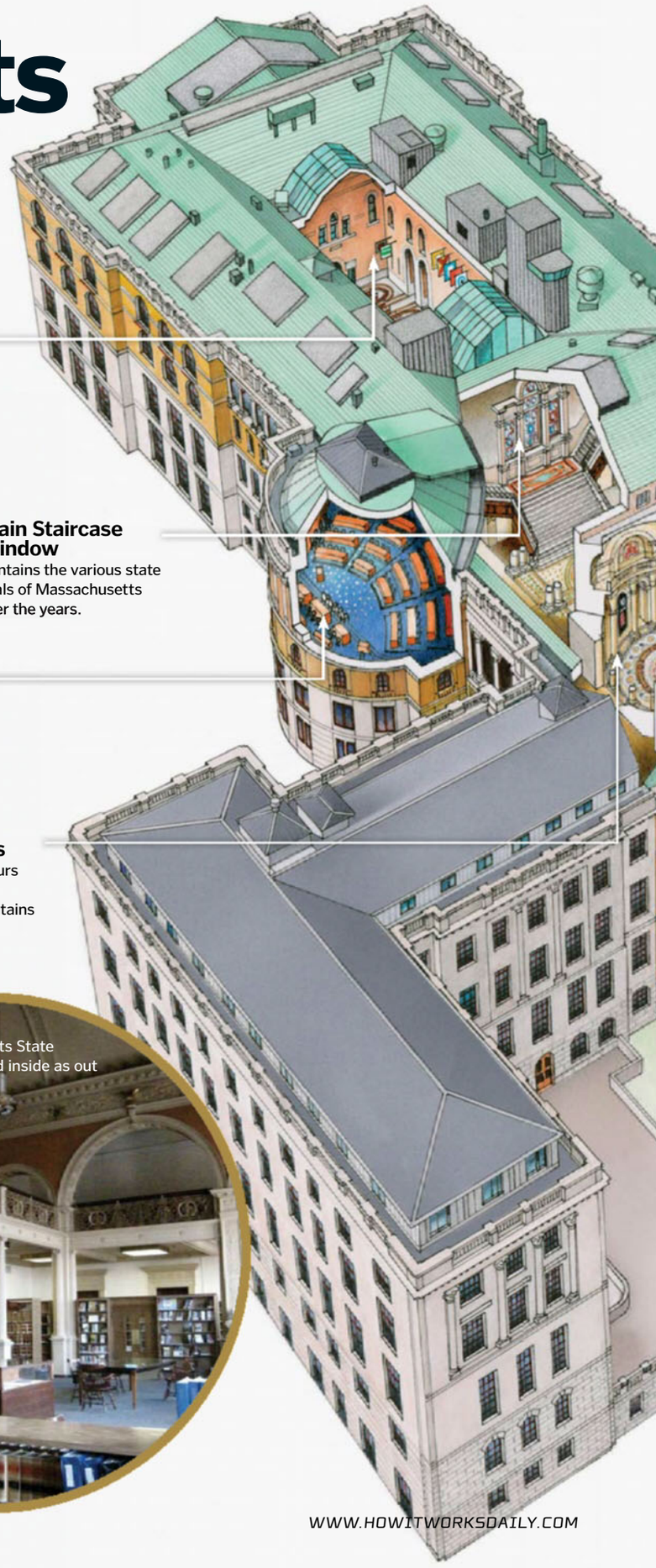
Why Boston's most iconic building has spades of symbolism to match its pomp

With the American Revolutionary War having ended in 1783, the still-young United States of America were striving to define their national identity. One of the ways in which the fledgling nation tried to achieve this was through the construction of grandiose and symbolic structures like Boston's capitol building, the Massachusetts State House.

The building was the brainchild of architect Charles Bulfinch, who took much of his inspiration from the two years he spent travelling around Europe. Construction commenced in 1795, with Patriots Samuel Adams and Paul Revere laying down its cornerstone in its location on top of Beacon Hill – a site once owned by John Hancock, the first elected governor of Massachusetts. Completed in 1798, it became an instant landmark, towering over the low-lying rest of the city and giving true credence to John Winthrop's epitaph of "a city on a hill."

The dome atop the State House is perhaps the section of its exterior that has changed the most over the years. Originally made of wood, it was overlaid with copper in the early-19th century before being covered in gold in 1874. During the Second World War it was painted dark for protection against the possibility of air raids during blackouts. The roof was finally re-gilded in 1997. On top of the dome itself is a wooden pine cone, symbolising the economic and cultural importance of the logging industry in the state's history.

Today, it still functions as the state's capitol building, hosting the Senate and House of Representatives' Chamber. Hanging up in the gallery in direct view of the Representatives is one of the most culturally significant sights in Boston: the Sacred Cod, which symbolises the importance of Boston's fishing industry to its prosperity. Combined with the numerous pieces of artwork and treasure in the building's confines, it's fair to say the building's history is extensive and far-reaching.

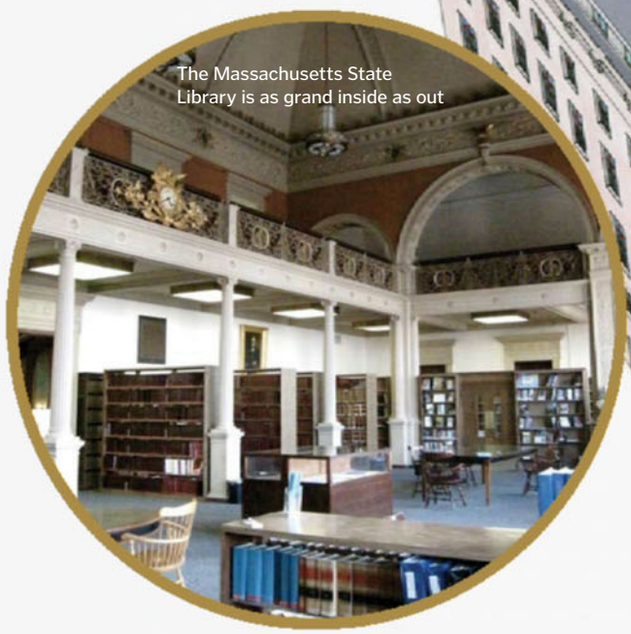


Great Hall
The newest addition to the building, construction was completed in 1990.

Main Staircase Window
Contains the various state seals of Massachusetts over the years.

House of Representatives
Home to the famous Cod, the chamber is situated on the third floor.

Hall of Flags
This room honours Massachusetts' soldiers and contains over 400 flags.



The Massachusetts State Library is as grand inside as out

5 TOP FACTS
BULFINCH DESIGNS

United States Capitol
1 Bulfinch oversaw construction of the Capitol Building between 1818 and 1826, having modified the original concept. He is responsible for the design of the dome in the centre.

University Hall
2 Having studied at Harvard, it's fitting that Bulfinch went on to design one of its most iconic buildings. It was built from 1813-1815 and is a US National Historic Landmark.

Maine State House
3 Based on his designs for the Massachusetts State, construction took place from 1829-32. It was later expanded on in 1911, with much of the old building being demolished.

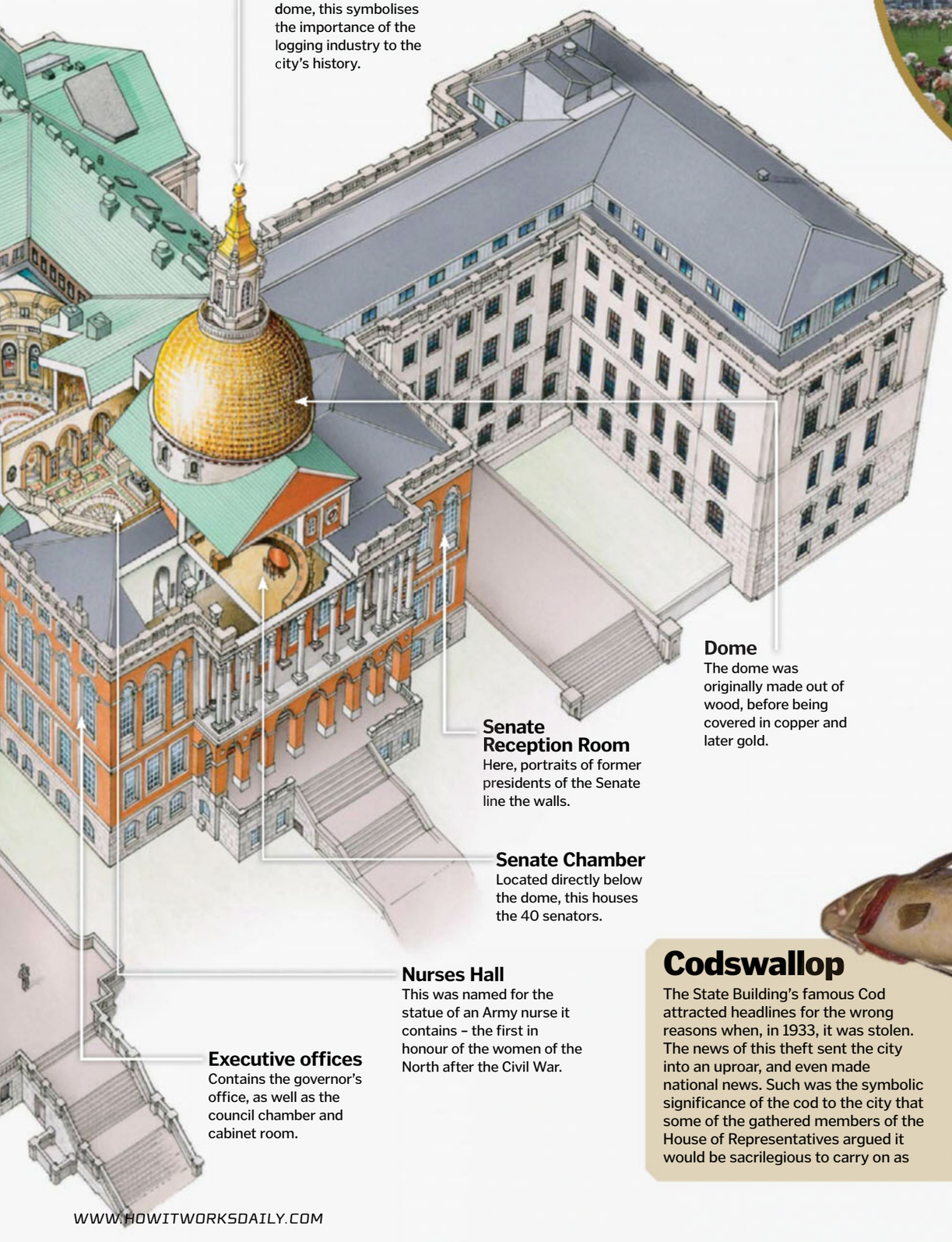
First Church of Christ Unitarian
4 Bulfinch's last project before working on the Capitol. Although smaller in scale, this is no less impressive than his previous work.

The Bulfinch Building
5 Part of the Massachusetts General Hospital, construction of the building to bear the architect's name took place from 1818-23, and is also a National Historic Landmark.

DID YOU KNOW? *The Massachusetts State House can be seen in numerous scenes in Martin Scorsese's 2006 film* The Departed

Inside the State House

Your guide to the most important features of the Massachusetts State House



Pine cone
Located on top of the dome, this symbolises the importance of the logging industry to the city's history.

Dome
The dome was originally made out of wood, before being covered in copper and later gold.

Senate Reception Room
Here, portraits of former presidents of the Senate line the walls.

Senate Chamber
Located directly below the dome, this houses the 40 senators.

Nurses Hall
This was named for the statue of an Army nurse it contains – the first in honour of the women of the North after the Civil War.

Executive offices
Contains the governor's office, as well as the council chamber and cabinet room.

Inspirations for the State House's design

During his travels, Bulfinch drew on inspiration from a number of styles, which coalesced to form a building with a style of its own. One of the styles that can be most clearly observed in the building's design is Palladian in nature, drawing on the design themes present in the work of Italian architect Andrea Palladio (1508-80), notably the kind of symbolism seen in classical Greek architecture. A famous example of this can be seen in Somerset House, London (above), with the central part of the State House bearing the most obvious parallels with Palladian architecture.

In addition, Bulfinch's work evoked the neoclassical styles embodied by the likes of Scottish architect Robert Adam (1728-92), although in a move that evoked themes closer to home, wood was used for the columns in the colonnade, as well as for parts of the stairs and decorative bands on the columns.

Codswallop

The State Building's famous Cod attracted headlines for the wrong reasons when, in 1933, it was stolen. The news of this theft sent the city into an uproar, and even made national news. Such was the symbolic significance of the cod to the city that some of the gathered members of the House of Representatives argued it would be sacrilegious to carry on as normal without the famous fish looking over them.

The cod was eventually recovered (with only minor damage) by Harvard Yard police chief Charles Apted, with the cod-napping being blamed on the staff of *The Lampoon*, Harvard University's comedy magazine, although none if its members were ever charged.

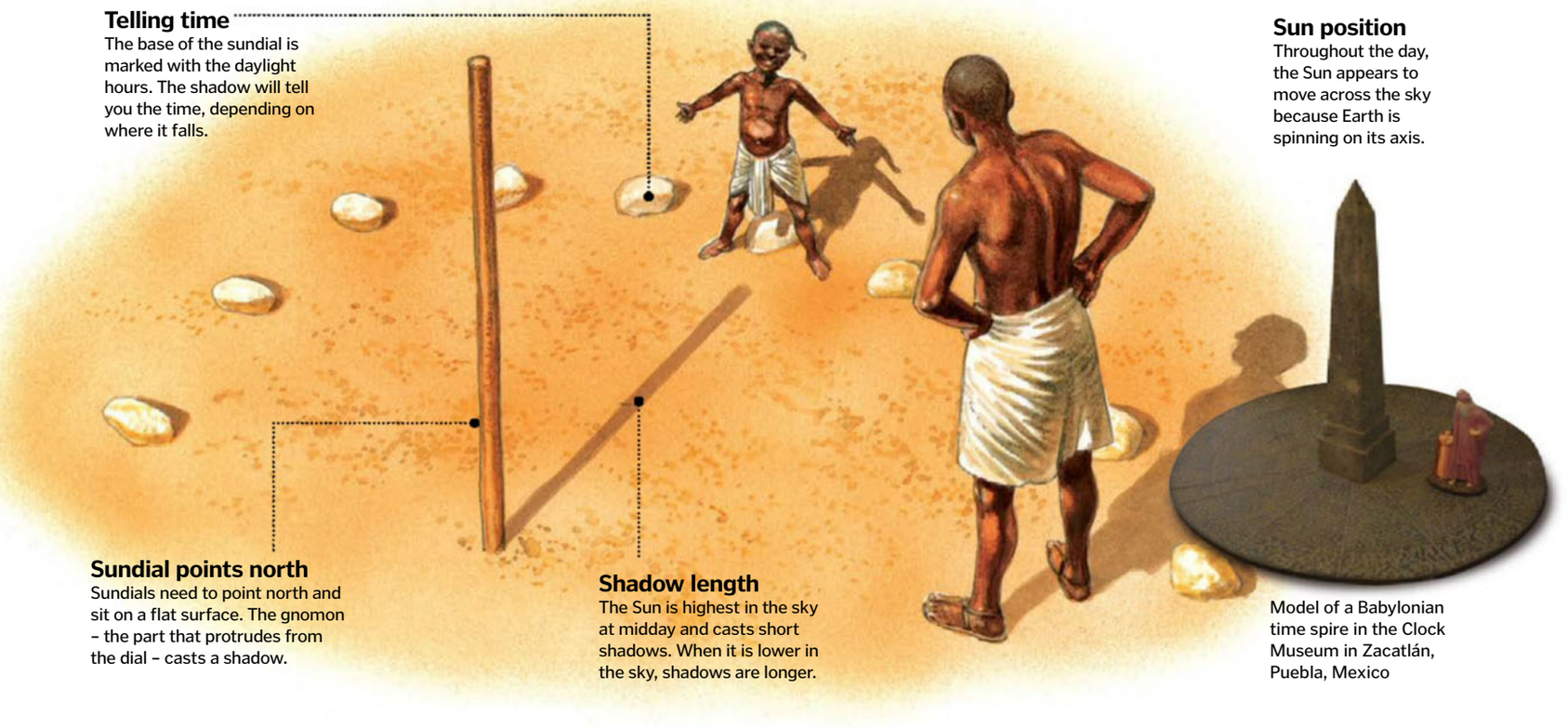
"When a shadow is present on a specific number, that is the current hour"

How sundials tell the time

Discover how this ancient contraption worked

The sundial is one of the world's oldest scientific instruments. Designed to tell the time to the nearest hour, the ancient contraption was first created by the Babylonian and Egyptian civilisations and works by measuring the Sun's movement across the sky.

The mechanism's dial is known as a gnomon or style and contains numerals representing the hours of the day, so when a shadow (or shard of light in some variations) is present on a specific number, that is the current hour. Sundials vary by their latitude. The Sun appears to take various paths across the sky in different parts of the world so a sundial must be tailored for the location it is in. Also, the time shown can vary by how close it is to a time-zone boundary. Clearly, they work better in sunnier areas, so they are more effective in the Mediterranean than in England!



Telling time
The base of the sundial is marked with the daylight hours. The shadow will tell you the time, depending on where it falls.

Sun position
Throughout the day, the Sun appears to move across the sky because Earth is spinning on its axis.

Sundial points north
Sundials need to point north and sit on a flat surface. The gnomon – the part that protrudes from the dial – casts a shadow.

Shadow length
The Sun is highest in the sky at midday and casts short shadows. When it is lower in the sky, shadows are longer.

Model of a Babylonian time spire in the Clock Museum in Zacatlán, Puebla, Mexico

Epsom salts

A chemical compound with healing properties

The story goes that the use of Epsom salts began in the 17th century when a farmer from Epsom in Surrey, England, noticed that his cows would not drink from a particular spring of water. During a drought, the farmer was not as picky as his herd and drank the water, which seemed to heal a rash on his arm.

News of the healing effects of the water spread by word of mouth and Epsom became a popular spa town. It was later discovered that the water contained magnesium sulphate, which has a range of health benefits. In the human body, a dose of magnesium can relieve muscle and nerve pain. Sulphur is used to make antioxidants in the body, which help get rid of toxins.

Epsom salts are now obtained from spring sources worldwide but can also be manufactured in laboratories. They play an important role in many medical procedures, as well as spa treatments.

After its discovery in the 17th century, Epsom salts became a common fixture in many baths and spas

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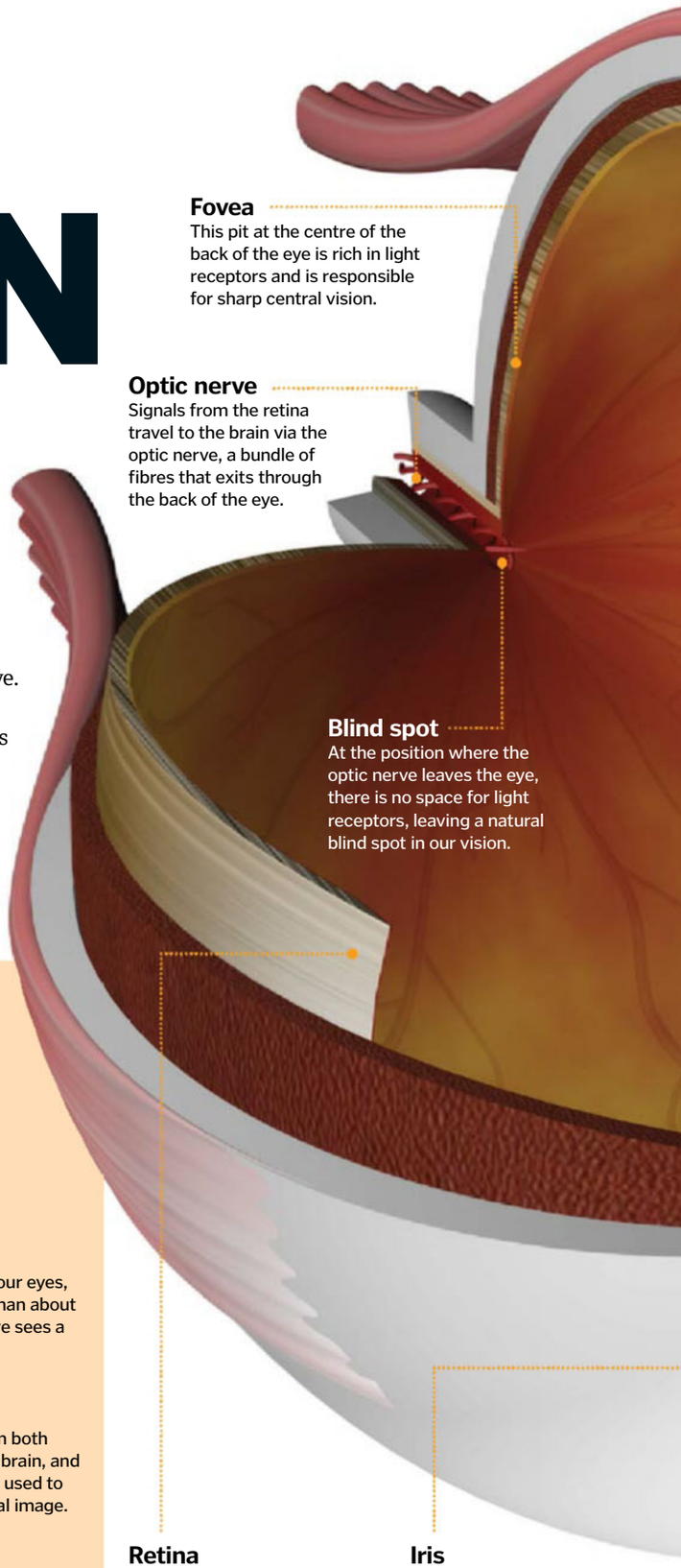
SCIENCE OF VISION

Uncovering one of the most complex constructs in the natural world

The structure of the human eye is so complex that it's hard to believe that it's not the product of intelligent design, but by looking at the eyes of other animals, scientists have shown that it evolved very gradually from a simple light-dark sensor over the course of around 100 million years. It functions in a very similar way to a camera, with an opening through which the light enters, a lens for focusing and a light-sensitive membrane at the back.

The amount of light that enters the eye is controlled by the circular and radial muscles in the iris, which contract and relax to alter the size of the pupil. The light first passes through a tough protective sheet called the cornea, and then moves into the lens. This adjustable structure bends the light, focusing it down to a point on the retina, at the back of the eye.

The retina is covered in millions of light-sensitive receptors known as rods and cones. Each receptor contains pigment molecules, which change shape when they are hit by light, triggering an electrical message that travels to the brain via the optic nerve.



Fovea
This pit at the centre of the back of the eye is rich in light receptors and is responsible for sharp central vision.

Optic nerve
Signals from the retina travel to the brain via the optic nerve, a bundle of fibres that exits through the back of the eye.

Blind spot
At the position where the optic nerve leaves the eye, there is no space for light receptors, leaving a natural blind spot in our vision.

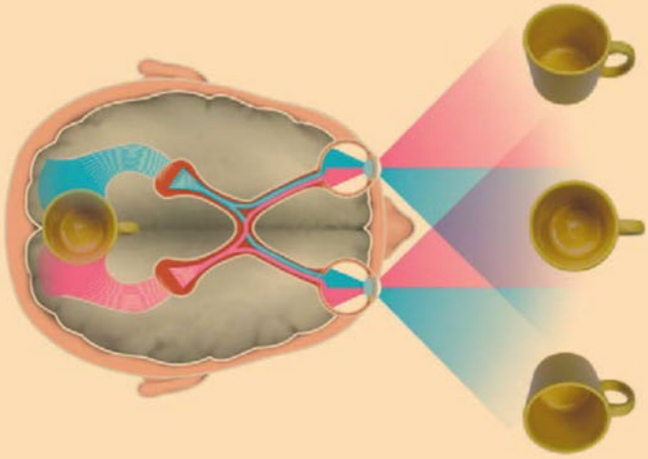
Retina
The retina is covered in receptors that detect light. It is highly pigmented, preventing the light from scattering and ensuring a crisp image.

Iris
This circular muscle controls the size of the pupil, allowing it to be closed down in bright light, or opened wide in the dark.

Seeing in three dimensions

Each eye sees a slightly different image, allowing the brain to perceive depth

Our eyes are only able to produce two-dimensional images, but with some clever processing, the brain is able to build these flat pictures into a three-dimensional view. Our eyes are positioned about five centimetres (two inches) apart, so each sees the world from a slightly different angle. The brain compares the two pictures, using the differences to create the illusion of depth.



Individual image
Due to the positioning of our eyes, when objects are closer than about 5.5m (18ft) away, each eye sees a slightly different angle.

Combined image
The incoming signals from both eyes are compared in the brain, and the subtle differences are used to create a three-dimensional image.

Try it for yourself
By holding your hand in front of your face and closing one eye at a time, it is easy to see the different 2D views perceived by each eye.

HEAD 2 HEAD

AN EYE FOR SIZE

Tarsier

The eyes of these tiny primates are as big as their brains, so as a result, they have developed extremely good night vision.

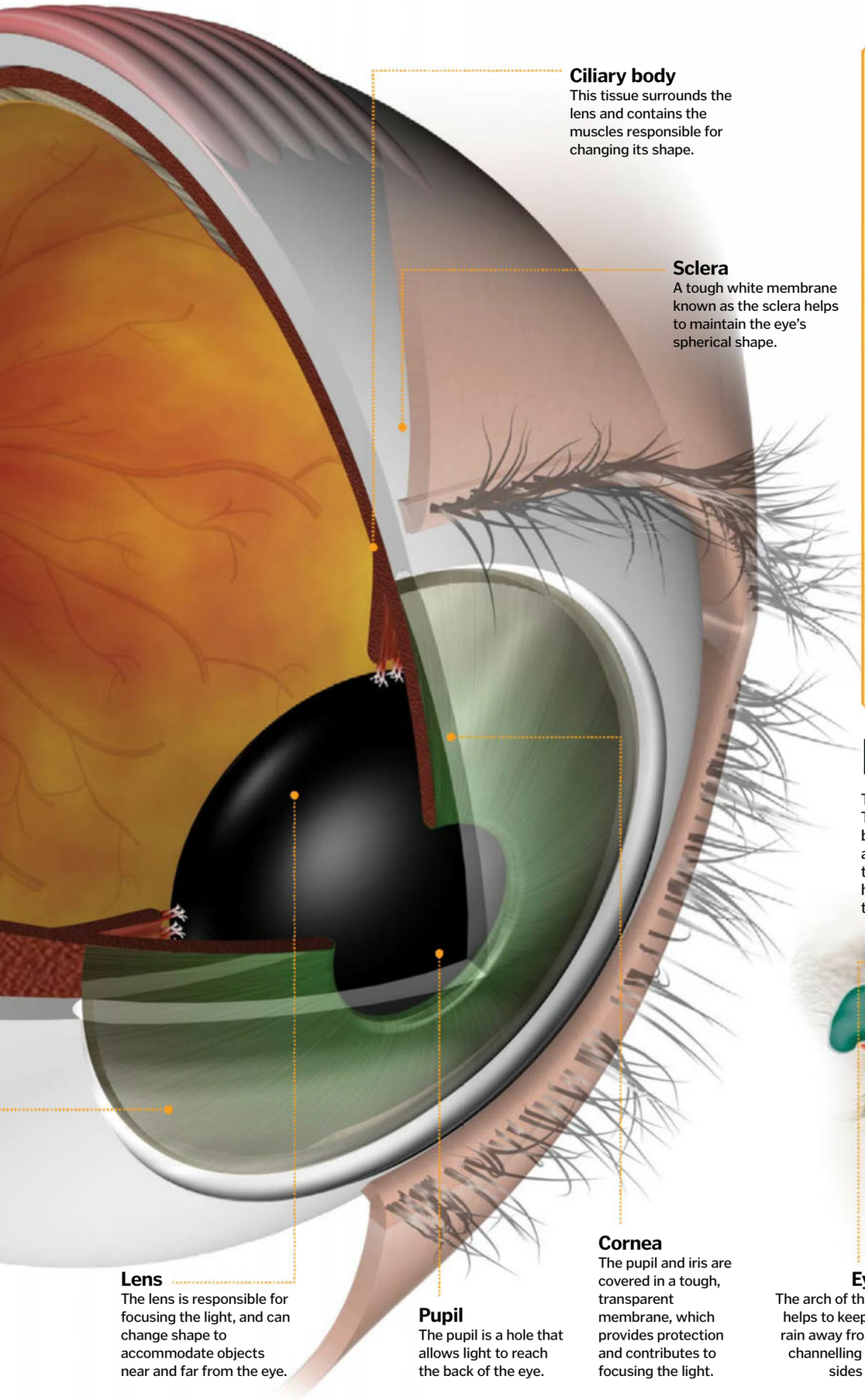
Ostrich

Ostriches are the largest living birds and also have the largest eyes of any living land animal, measuring an incredible 5cm (2in) in diameter.

Colossal squid

Little is known about these mysterious creatures, but they have eyes the size of footballs – the largest known in the animal kingdom.

DID YOU KNOW? *285 million people in the world are estimated to be visually impaired and 39 million of them are blind*



Ciliary body

This tissue surrounds the lens and contains the muscles responsible for changing its shape.

Sclera

A tough white membrane known as the sclera helps to maintain the eye's spherical shape.

Lens

The lens is responsible for focusing the light, and can change shape to accommodate objects near and far from the eye.

Pupil

The pupil is a hole that allows light to reach the back of the eye.

Cornea

The pupil and iris are covered in a tough, transparent membrane, which provides protection and contributes to focusing the light.

Vision problems

The most common problems with our eyesight

Farsightedness (hyperopia)

If the eye is too short, the cornea is too flat, or if the lens sits too far back, incoming light is focused behind the retina, making nearby objects appear blurry, particularly in the dark.

Nearsightedness (myopia)

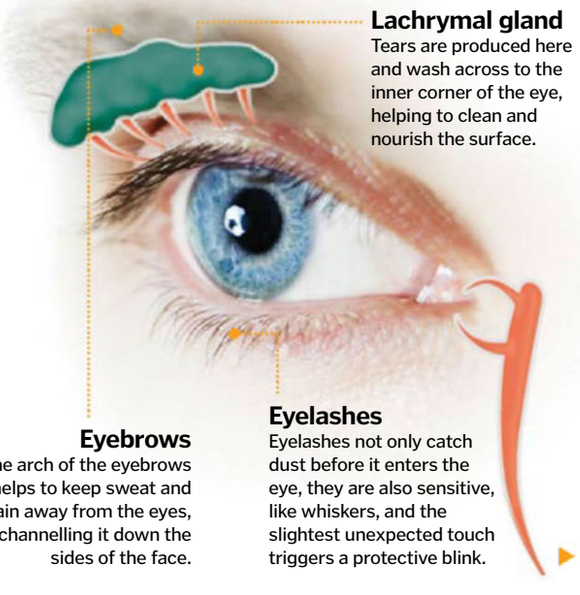
If the eye is too long, or the cornea and lens are too curved, the light is focused before it hits the back of the eye, and then starts to defocus again as it reaches the retina, making distant objects difficult to see.

Colour-blindness

This rare condition is often linked to a gene on the X-chromosome and occurs more commonly in men than in women. A defect in the cone cells of the eye reduces the number of colours that can be detected.

Protection

The eyes are shielded by several layers of protection. They are almost completely encased in bone at the back and insulated from shock by layers of muscle and connective tissue. The front is kept moist with tears and constantly wiped by the eyelids, while the hairs of the eyebrows and eyelashes catch any debris that might fall in.



Lachrymal gland

Tears are produced here and wash across to the inner corner of the eye, helping to clean and nourish the surface.

Eyebrows

The arch of the eyebrows helps to keep sweat and rain away from the eyes, channelling it down the sides of the face.

Eyelashes

Eyelashes not only catch dust before it enters the eye, they are also sensitive, like whiskers, and the slightest unexpected touch triggers a protective blink.

"Each eye has between 6 and 7 million cone cells, containing colour-sensitive proteins known as opsins"

Colour vision

Why humans see the world in so many colours

Night monkeys have large eyes that enhance their nocturnal vision

Open your eyes, and you are met with an array of different colours, but amazingly you can only detect three different wavelengths of light, corresponding to green, blue, and red. Combining these three signals in the brain creates millions of different shades.

Each eye has between 6 and 7 million cone cells, containing one of three colour-sensitive proteins known as opsins. When photons of light hit the opsins, they change shape, triggering a cascade that produces electrical signals, which in turn transmit the messages to the brain. Well over half of our cone cells respond to red light, around a third to green light, and just two per cent to blue light, giving us vision focused around the yellow-green region of the spectrum.

The vast majority of the cone cells in the human eye are located in the centre of the retina, on a spot known as the fovea, measuring just fractions of a millimetre across. Light is focused on this point, providing a crisp, full-colour image at the centre of our vision. The remainder of the retina is dominated by 120 million rod cells, which detect light, but not colour.

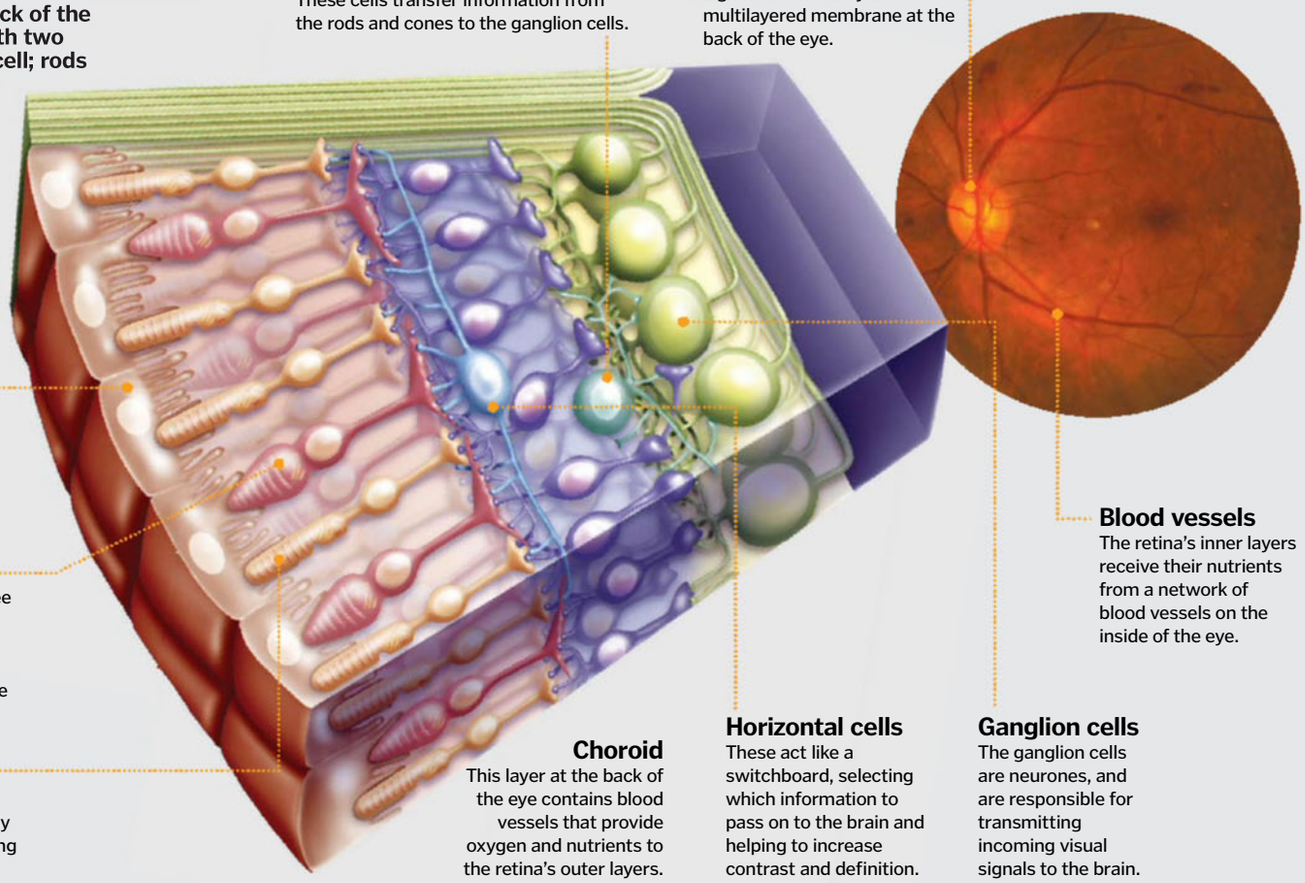
We are so used to seeing the world in red, green and blue that it might seem strange to think that most other animals cannot, but three-coloured vision like our own is relatively unusual. Some species of fish, reptiles and birds have four-colour vision, able to see red, green, blue and ultraviolet or infrared light, but during mammalian evolution, two of the four cone types were lost, leaving most modern mammals with dichromatic vision – seeing in shades of just yellow and blue.

This was not a problem for many early mammals, because they were largely nocturnal, and lived underground, where there was little need for good colour vision. However, when primates started moving into the trees, a gene duplication gave some species the ability to see red, providing a significant evolutionary advantage in picking out ripe red fruit against the green leaves.

Even today, not all primates can see in three colours; some have dichromatic vision, and many nocturnal monkeys only see in black and white. It is all down to environment; if you don't need to see all of the colours in order to survive, then why waste energy making the pigments?

Light and colour

As light hits the back of the eye, it interacts with two different types of cell; rods and cones



Amacrine and bipolar cells
These cells transfer information from the rods and cones to the ganglion cells.

Retina
Light is detected by a multilayered membrane at the back of the eye.

Sclera
The white part of the eye continues all the way to the back of the retina, providing structural support.

Pigment epithelium
This dense sheet of cells contains dark pigment granules, which absorb excess light, preventing it from scattering inside the eye.

Cone cell
The human eye has three types of light-sensitive cone cell, each for a different wavelength of light, red, green and blue respectively.

Rod cell
Rod cells cannot detect colour, but are extremely sensitive to light, allowing us to see in the dark.

Choroid
This layer at the back of the eye contains blood vessels that provide oxygen and nutrients to the retina's outer layers.

Horizontal cells
These act like a switchboard, selecting which information to pass on to the brain and helping to increase contrast and definition.

Ganglion cells
The ganglion cells are neurones, and are responsible for transmitting incoming visual signals to the brain.

Blood vessels
The retina's inner layers receive their nutrients from a network of blood vessels on the inside of the eye.

How many eyes does a giant clam have?

A Two **B** None **C** Thousands

Answer:
Giant clams can grow to over 1m (3.3ft) in length, and their soft, fleshy mantle is a tasty target for predators. Around the edges, thousands of pinhole eyes watch for changes in light and shadow, allowing them to close quickly in response to danger.

DID YOU KNOW? *The eye muscles are the most active muscles in the body. They move more than 100,000 times a day.*

How we see

Look around you – do you know what you're seeing with?

The back of the eye is covered in a layer of light-sensitive cells measuring just fractions of a millimetre in thickness. When photons of light hit the pigments inside the cells, it triggers a cascade of signals, which pass through a series of different connections before they are transmitted to the brain.

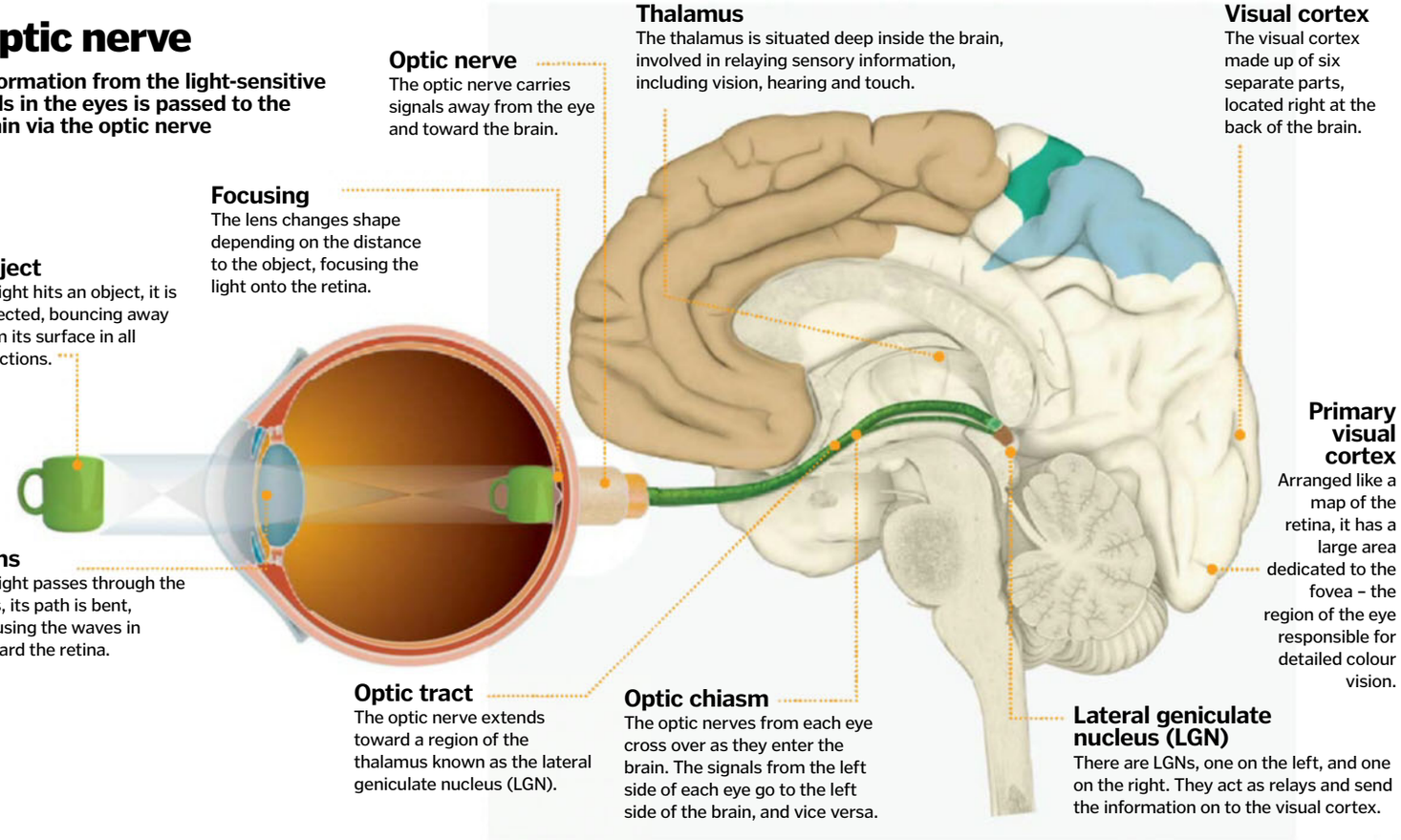
First, they move through interneurones and then to neurones known as ganglion cells. These cells are cross-linked, able to compare adjacent signals, filtering out some of the information before passing it on to the brain. This helps to improve contrast and definition. The neurones travel across the back surface toward the optic nerve, which relays the information into the brain.

As the two optic nerves enter the brain, they cross over, coming together at a point known as the optic chiasm. Here, signals from the left side of both eyes are diverted to the left side of the brain, and vice versa, allowing the images from both eyes to be combined and compared.

The signals enter the brain via the thalamus, which separates the incoming information into two parts, one containing colour and detail, and the other movement and contrast. The messages then move to the back of the brain, and into the visual cortex. The cortex is laid out so that it mirrors the back of the retina, allowing a detailed image to be reconstructed.

Optic nerve

Information from the light-sensitive cells in the eyes is passed to the brain via the optic nerve



Quick-fire questions

Why do we see in black and white at night?

The colour-sensitive cone cells in the eye function like slow camera film – they produce highly detailed images, but require lots of light to work. In contrast, light-sensitive rod cells are like fast film. They respond to low levels of light, but cannot detect colour, producing a grainy, black-and-white image.

Why does our eyesight get worse as we get older?

As the eye ages, the lens becomes less flexible, making it increasingly difficult to focus on nearby objects. Luckily, this is easily corrected with glasses. Cloudy areas, known as cataracts, can also start to appear within the lens, making vision appear blurred or misty, but this can often be fixed with simple surgery.

Why do our eyes jump instead of moving around smoothly?

Movement of the eye is controlled by the brainstem. Our vision would be blurry if our eyes moved smoothly, so they jump in steps known as saccades. The brain stitches the images together, like the frames in a film, producing the illusion of continuous movement.

Why do some animals have their eyes on the sides of their head?

Forward-facing eyes are incredibly useful for primates, who need to be able to accurately judge depth when jumping between trees, for example, and for predators who need to pinpoint their prey. In contrast, prey animals need to be able to watch for danger, and often sacrifice binocular vision for a more rounded view of their environment.

"Rather than seeing in three colours, most birds can see four, extending their visual range"

How animals see the world

Take a look at the world through a different set of eyes

Each panel shows how each animal would see this picture

DOG

For a long time, it was thought dogs saw the world in black and white, distinguishing between objects only based on differences in light and contrast. It is now known that they have two-colour vision, seeing the world in shades of yellow and blue. Dogs have good night vision and the back of their eye contains a reflective layer known as tapetum, which helps to maximise light detection in the dark. However, the central part of their retina is only 20 per cent cone cells (compared to 100 per cent in humans), so although they see better in low light, their daytime vision is much less detailed than our own.

BIRD

Birds have arguably the most advanced vision in the animal kingdom. Rather than seeing in three colours, most birds can see four, extending their visual range into the ultraviolet part of the spectrum. Each of their cone cells also contains a drop of oil, which acts as a filter, further increasing their visual acuity. Why birds evolved the ability to see ultraviolet light is unclear. Some have UV-reflective feathers, others use their keen eyesight to spot UV-bright moths, butterflies, and fruits, and birds of prey use their UV vision to track rodents, picking up on their bright urine trails among the dense vegetation in the fields.

INSECT

Insects are so small that if they had eyes like ours, the tiny lens would be unable to bend and focus the light. Instead, they have compound eyes, built from many smaller units known as ommatidia. Each has its own lens, a crystalline cone, pigments and light-sensitive cells, and together they create a mosaic, similar to the pixels on a television screen. The more ommatidia an insect has, the higher the resolution of the image. Some insects, like dragonflies, have around 50,000 of these units, giving them a clear view of the world around them, allowing them to rapidly detect movement in their environment.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

See the world through the eyes of animals

www.howitworksdaily.com

DID YOU KNOW? *We blink about 12 times a minute. When we do, tears are spread over the front of the eyeball to keep them moist*

ABOVE The original image from below, with a colour spectrum as seen by humans

SNAKE

Pythons, boas and pit vipers have eyes surprisingly similar to our own, but they are able to see something we can't. Using specialist pit organs near their noses, these snakes can 'see' heat. The pits have a pinhole opening and at the bottom is a membrane similar to the retina, with a tightly packed network of heat-sensitive neurones – between 500 and 1,500 cells per square millimetre. The signals from the eyes and the pits converge on the same point in the brain, allowing the snakes to produce a combined visual and thermal image, or to switch between the two, like putting on a pair of night-vision goggles.

RAT

Rats are much more responsive to changes in brightness than colour, and they were originally thought to be colour-blind – 99 per cent of the light-sensitive cells in their eyes are rods. However, it is now known that they are able to detect some colour. Most (88 per cent) of their cone cells are sensitive to green light, but the remainder allow them to detect light in the blue-ultraviolet end of the spectrum. This ability allows the rodents to see territorial urine marks left by other animals. Because they rely on rod cells to see, their visual acuity is low and their vision is much blurrier than our own.

HORSE

Horses have their eyes on the sides of their head, so they have a much wider field of view that we do. However, they cannot see directly in front of themselves at close range and have a triangular blind spot that extends about 1.2 metres (4 feet) in front of their faces. At longer distances, the horse can use both eyes together for binocular vision, but they are also able to use each eye separately. With one eye looking forward and one looking back, they can keep a careful watch for potential danger. Like most other mammals, they cannot see red, so their world is a combination of shades of yellow, blue, green and grey.

"Once both sections of bone are connected again, specialised cells called osteoblasts produce bone cells"

Bone fracture healing process

Learn how your body mends broken bones

If a bone has too much pressure put on it, there is a chance it will break. Your body has ways of repairing these breaks, but it takes time and care. There are different kinds of break, ranging from a hairline fracture to a fully shattered bone, but they all mend in a similar way.

As a bone breaks, the blood vessels are also severed. Blood leaks out and forms a clot called a fracture haematoma. This stops blood flow to the area and also helps keep both pieces of bone aligned, ready for healing.

The body then makes fibrous cells and cartilage, which reinforce the bond and strengthen it. This creates a callus, which is essentially a weakened bone. Over time, the callus builds up and the two parts of the bone gradually fuse together, like a bridge being constructed from either side of a river until both ends meet in the middle.

Once both sections of bone are connected again, specialised cells called osteoblasts enter to produce bone cells. These new cells replace the callus, returning the bone to its original shape.

Much like repairing a broken toy with glue, the bone needs to be kept straight and steady for the fusion to happen correctly. This is why doctors will put a cast on the broken bone. The cast provides essential support, protection and stability, ensuring the broken bone doesn't move. A cast will generally stay on for a few weeks until the bond has become strong enough, but it could take months for a properly set bone to fully recover.

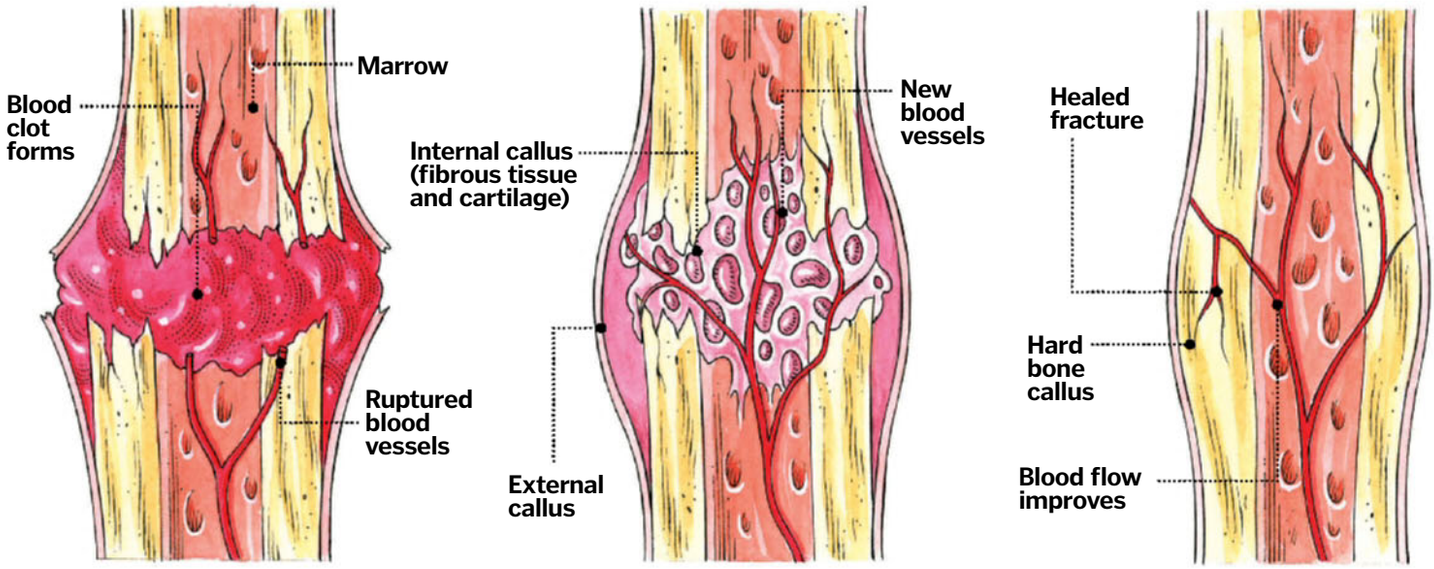
All-star cast

Most breaks on an arm or a leg will have a plaster cast put on them to prevent the bone from setting at a wonky angle or not setting at all.

It will generally be made from plaster of Paris. This is a mixture of water and gypsum that sets really hard once it has dried. The broken bone is bandaged and the wet mixture is applied to the gauze. Once it has dried then it should provide safety and stability for the bone.

Fibreglass is an increasingly common cast material. As with the plaster cast, the broken bone is bandaged up. Next, another bandage, made of fibreglass and layered with resin, is soaked in water. This makes it flexible enough to be wrapped around the bone before it hardens as it dries. This is much lighter than a plaster cast and the outer layer is waterproof.

The stages of bone repair



Blood clot
When a bone breaks, the blood vessels that run through the bone are severed. The blood forms a clot to align the bones. This creates a solid yet weak structure to prepare for mending. The clot also cuts off blood flow to the edges of the broken bone, so these cells die.

Tissue growth
A few days later, the blood clot – called the fracture haematoma – is gradually replaced by tougher tissue, which becomes a soft callus. Fibrous tissue and cartilage are produced that begin to bridge the gap between the fractured ends. New blood vessels begin to form and the callus usually lasts around three weeks.

Remodelling
Bone-forming cells called osteoblasts work in teams to build a new bone, creating a more solid structure called a hard bone callus. It takes several months to fill the cavity with harder bone, strengthened by nutrients like calcium and phosphorus. However, it may take longer for the bone to be completely healed.

5 TOP FACTS
LUNG TRIVIA

600 million alveoli
1 Alveoli are very small, but you have a lot of them. There are 300 million in each lung; that's 600 million in total! They all work to get oxygen into your blood.

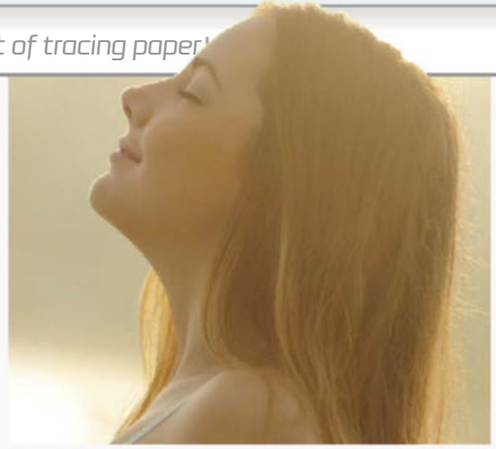
Lungs are different sizes
2 Your left lung is slightly smaller than your right, leaving room for your heart. It is also divided into two lobes, while the right lung has three.

Increase your capacity
3 Regular exercise isn't just good for your all-round health, it actually increases the lung capacity, which means they can send oxygen around the body faster.

Number of breaths
4 The average person at rest breathes 16 times per minute, which is 8,409,600 times per year! How many breaths have you taken in your lifetime?

Zero
5 The number of alveoli a bird has; they have replaced them with air sacs that allow a greater concentration of oxygen to be extracted – an advantage at high altitude.

DID YOU KNOW? *The cells lining an alveolus are about 50 times thinner than a sheet of tracing paper!*



How alveoli help you breathe

The lungs are filled with tiny balloon-like sacs that keep you alive

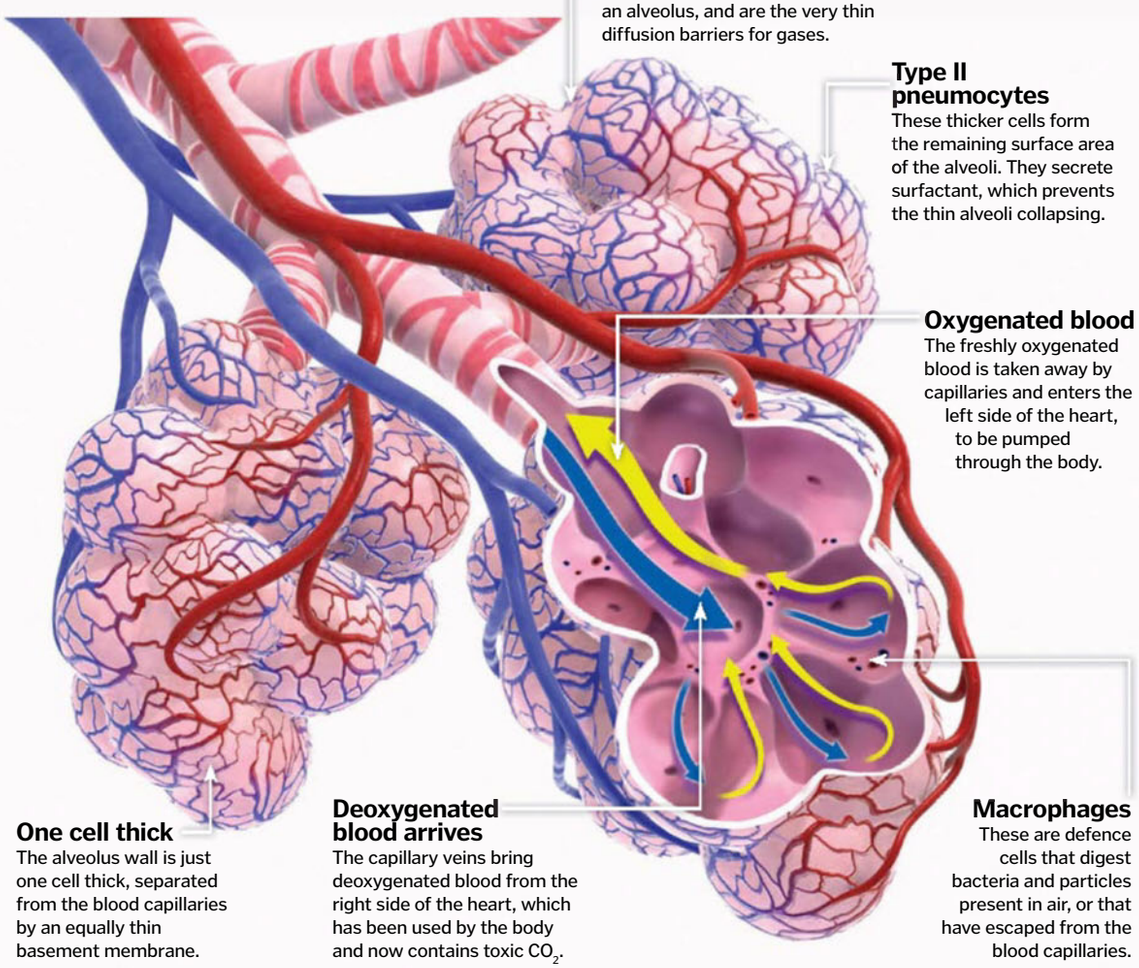
Gas exchange occurs in the lungs, where toxic gases (carbon dioxide) are exchanged for fresh air with its unused oxygen content. Of all the processes in the body that keep us functioning and alive, this is the most important. Without it, we would quickly become unconscious through accumulation of carbon dioxide within the bloodstream, which would poison the brain.

The two lungs (left and right) are made up of several lobes, and the fundamental building blocks of each are the tiny alveolus. They are the final point of the respiratory tract, as the bronchi break down into smaller and smaller tubes, leading to the alveoli, which are grouped together and look like microscopic bunches of grapes. Around the alveoli is the epithelial layer – which is amazingly only a single cell thick – and this is surrounded by extremely small blood vessels called capillaries. It is here that vital gas exchange takes place between the fresh air in the lungs and the deoxygenated blood within the capillary venous system on the other side of the epithelial layer.

The alveoli of the lungs have evolved to become specialised structures, maximising their efficiency. Their walls are extremely thin and yet very sturdy. Pulmonary surfactant is a thin liquid layer made from lipids and proteins that coats of all the alveoli, reduces their surface tension and prevents them crumpling when we breathe out. Without them, the lungs would collapse.

Alveoli anatomy

How alveoli enable gas exchange



Type I pneumocytes
These large, flattened cells form 95 per cent of the surface area of an alveolus, and are the very thin diffusion barriers for gases.

Type II pneumocytes
These thicker cells form the remaining surface area of the alveoli. They secrete surfactant, which prevents the thin alveoli collapsing.

Oxygenated blood
The freshly oxygenated blood is taken away by capillaries and enters the left side of the heart, to be pumped through the body.

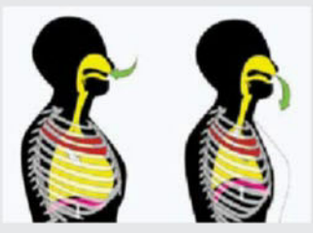
One cell thick
The alveolus wall is just one cell thick, separated from the blood capillaries by an equally thin basement membrane.

Deoxygenated blood arrives
The capillary veins bring deoxygenated blood from the right side of the heart, which has been used by the body and now contains toxic CO_2.

Macrophages
These are defence cells that digest bacteria and particles present in air, or that have escaped from the blood capillaries.

Breathe in, breathe out

The alveoli function to allow gas exchange, but since they're so small, they can't move new air inside and out from the body without help. That's what your respiratory muscles and ribs do, hence why your chest moves as you breathe. The diaphragm, which sits below your heart and lungs but above your abdominal organs, is the main muscle of respiration. When it contracts, the normally dome-shaped diaphragm flattens and the space within the chest cavity expands. This reduces the pressure compared to the outside atmosphere, so air rushes in. When the diaphragm relaxes, it returns to its dome shape, the pressure within the chest increases and the old air – now full of expired carbon dioxide – is forced out again. The muscles between the ribs (called intercostal muscles) are used when forceful respiration is required, such as during exercise Try taking a deep breath and observe how both your chest expands to reduce the pressure!



"As humans burn fossil fuels such as coal, oil or natural gases, carbon dioxide is released"

How kites fly

Understanding the forces that keep kites in the air

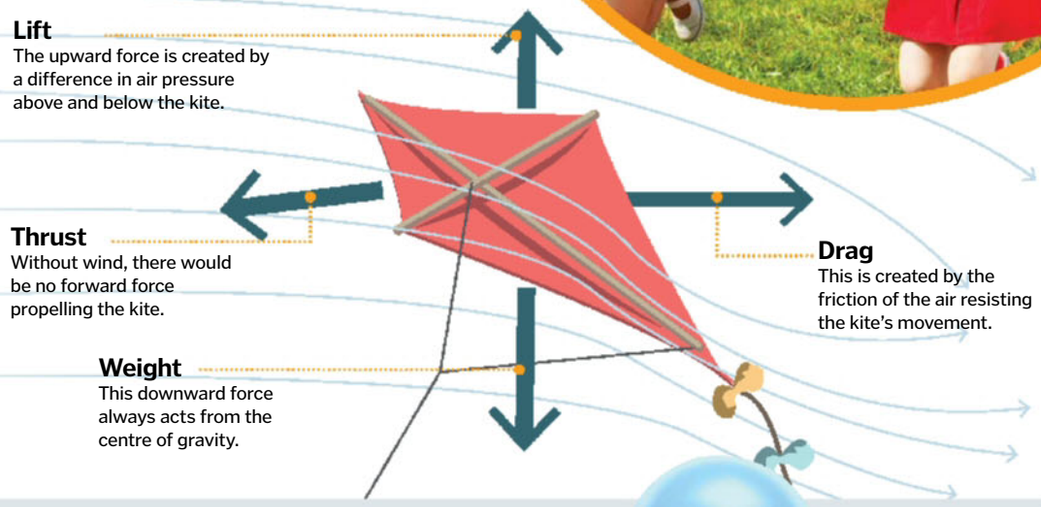
Kites are heavier than air, but they manage to defy gravity just like aeroplanes. That's because the same forces are acting upon them; lift, weight, drag and thrust. Kites are shaped so that the air travels over the top faster than the air moving underneath, which creates the upward force of lift. This is because the faster moving air above the kite creates an area of lower pressure.

However, the kite wouldn't sail into the air in the first place without wind. This generates thrust – the forward force – just like an aeroplane engine. There are two forces conspiring against the kite, however. These are weight, caused by the gravitational pull of Earth, and drag, which is the friction of air moving across the kite's surface. To fly, the force of lift must be greater than the weight.

Wind is crucial to flying a kite

Forces of flight

A kite needs the following four things to fly...



Lift
The upward force is created by a difference in air pressure above and below the kite.

Thrust
Without wind, there would be no forward force propelling the kite.

Drag
This is created by the friction of the air resisting the kite's movement.

Weight
This downward force always acts from the centre of gravity.

Carbon dioxide

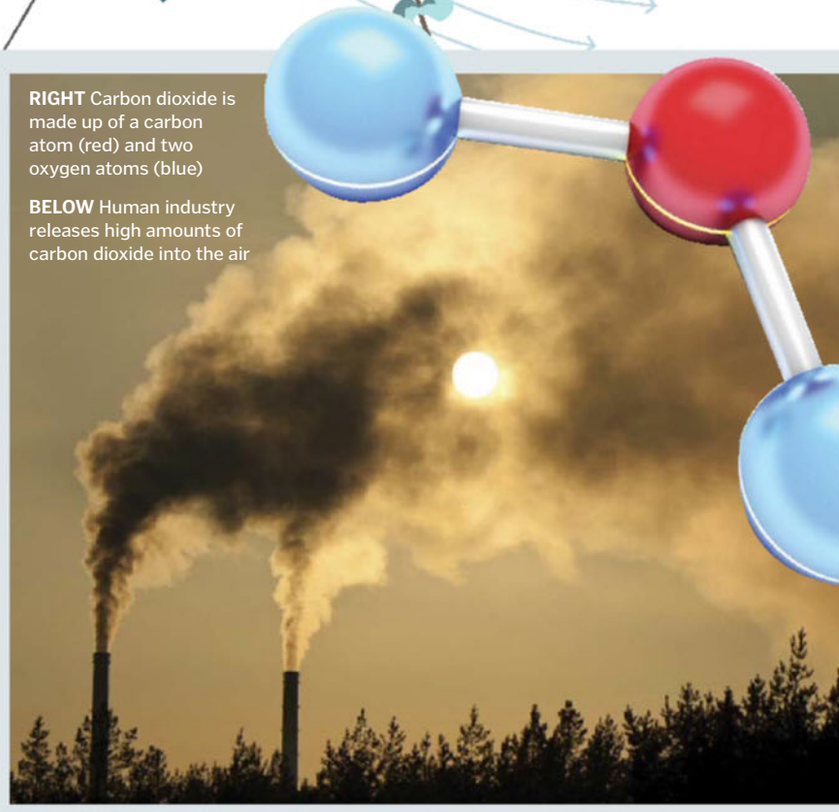
Our waste product is vital to life on Earth

Carbon dioxide is the fourth-most abundant gas in our atmosphere. It's a molecular compound consisting of a single carbon atom and two oxygen atoms. Carbon dioxide is vital to the regulation of Earth's temperature because it absorbs infrared radiation, trapping heat from the Sun.

As humans burn fossil fuels such as coal, oil or natural gases, carbon dioxide is released. This is because millions of years ago, fossil fuels were carbon-based life forms, so burning them releases that in the form of a gas. This increases the amount of heat trapped in the atmosphere, which is where the phrase 'global warming' comes from.

Carbon dioxide's main natural use is in the process of photosynthesis. Plants mix the carbon dioxide in the air with water to create glucose, which is their energy source.

This three-atom element is also commonly used in the soft drinks industry to create that familiar fizz they make. Highly pressurised carbon dioxide is forced into drinks, where water molecules form barriers around the carbon dioxide molecules, making individual bubbles that explode upward when the pressure is released.



RIGHT Carbon dioxide is made up of a carbon atom (red) and two oxygen atoms (blue)

BELOW Human industry releases high amounts of carbon dioxide into the air

THE STATS EXTREME ELEMENTS

LOWEST BOILING POINT
Helium -269°C
LOWEST MELTING POINT
Helium -272°C

HIGHEST BOILING POINT
Tungsten
5,660°C

LOWEST DENSITY
Hydrogen
0.09g/cm^3

HIGHEST DENSITY
Osmium
22.6g/cm^3

HIGHEST MELTING POINT
Carbon
3,500°C

DID YOU KNOW? *It is estimated that 99 per cent of the visible matter in the universe is plasma*

The 'other' states

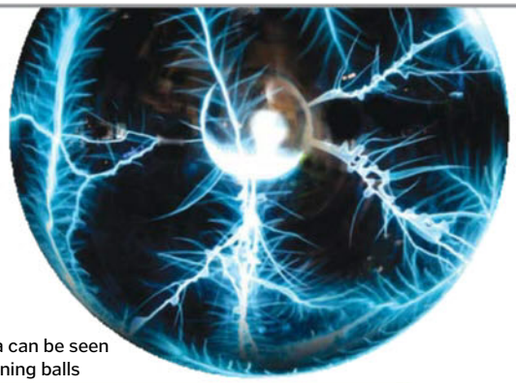
There's more to this world than solid, liquid and gas...

From the water you're drinking to the phone in your pocket, everything on Earth is a state of matter. It is the distribution of these different states and the atoms within them that make up the environment around us. The three primary states are solid, liquid and gas.

However, a fourth state of matter exists, and that occurs when a gas is pumped so full of energy that both ions and electrons are able to exist within it. This fourth state is called plasma and is commonly seen in lightning and auroras. Humans can only create it under strict laboratory conditions, but it is actually the most abundant state of matter in the universe. Every star you see in sky is a great big ball of burning hot plasma, including our own Sun.

Other states of matter are being uncovered, in addition to the big four. Bose-Einstein condensate, for example, is roughly the opposite of plasma. It forms at super-low temperatures, just above the temperature of absolute zero where all molecular motion ceases. One element that can enter this state is the alkali metal rubidium. Out of this state superfluids and supersolids can form, which have incredible properties. Some seem to defy gravity and others are incredibly efficient at conducting heat.

There's also a rare type of state called strange matter. Like any other states of matter it contains quarks (the elementary particles inside atomic nuclei), but instead of staying confined within protons and neutrons, the quarks in strange matter move freely. Scientists are yet to find this state in nature, but it's possible that it exists in super-dense neutron stars. Strange matter indeed.



Plasma can be seen in lightning balls

Phase changes

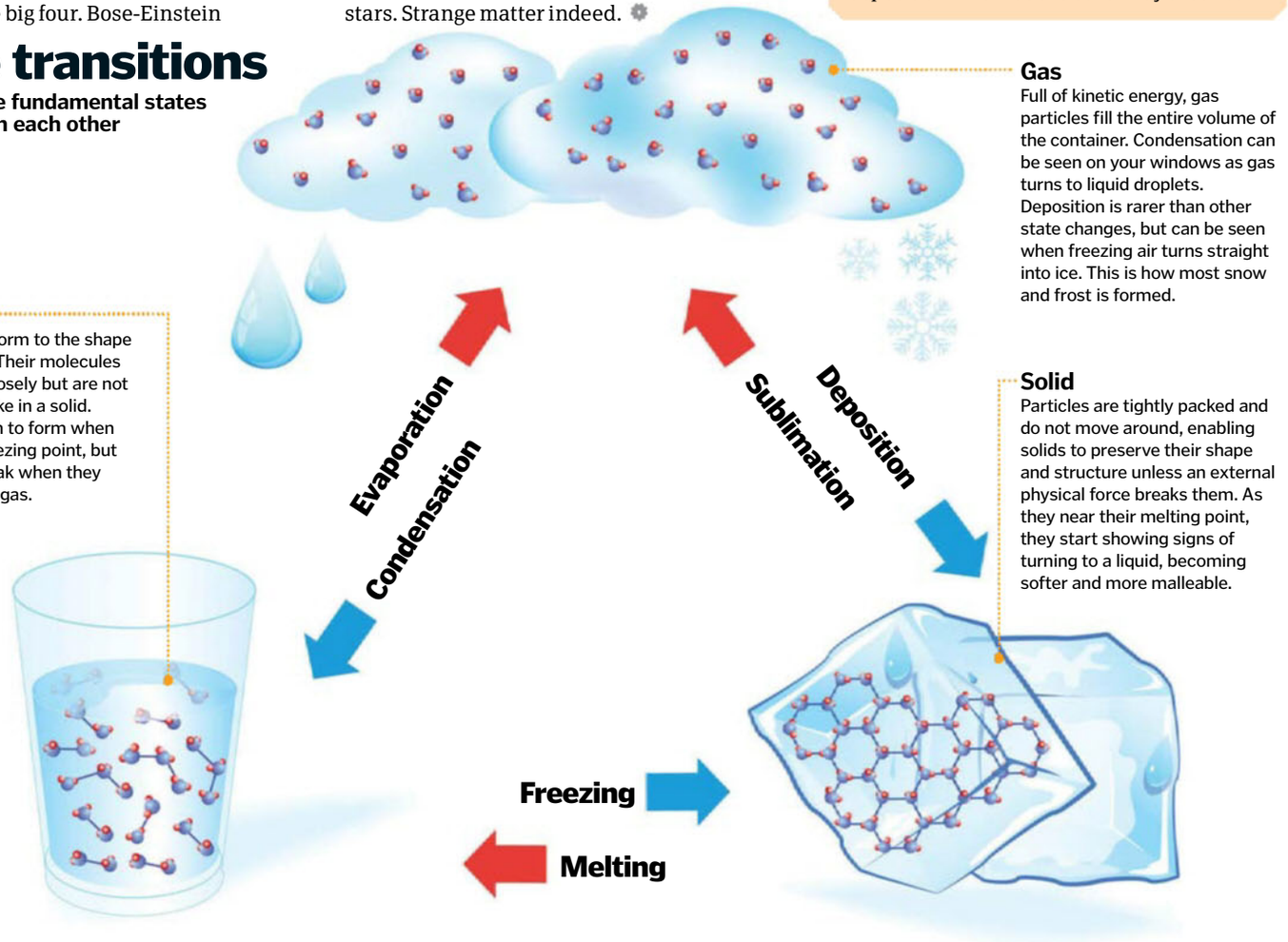
What causes a substance to alter?

A change of state is also known as a phase change. These occur when a substance changes between a solid, liquid or gas while not changing its molecular composition. For example, solid ice melts into liquid water but both are made up of water molecules.

Changes happen when specific limits are reached such as freezing, melting and boiling points. Liquid is often the middleman, but it's possible for solids and gases to change into each other without going through the liquid phase. It is called sublimation when solid goes to a gas, and deposition when it's the other way around.

Phase transitions

How the three fundamental states cycle between each other



"We can artificially engineer aromas by creating pleasant-smelling chemicals known as esters"

Additives

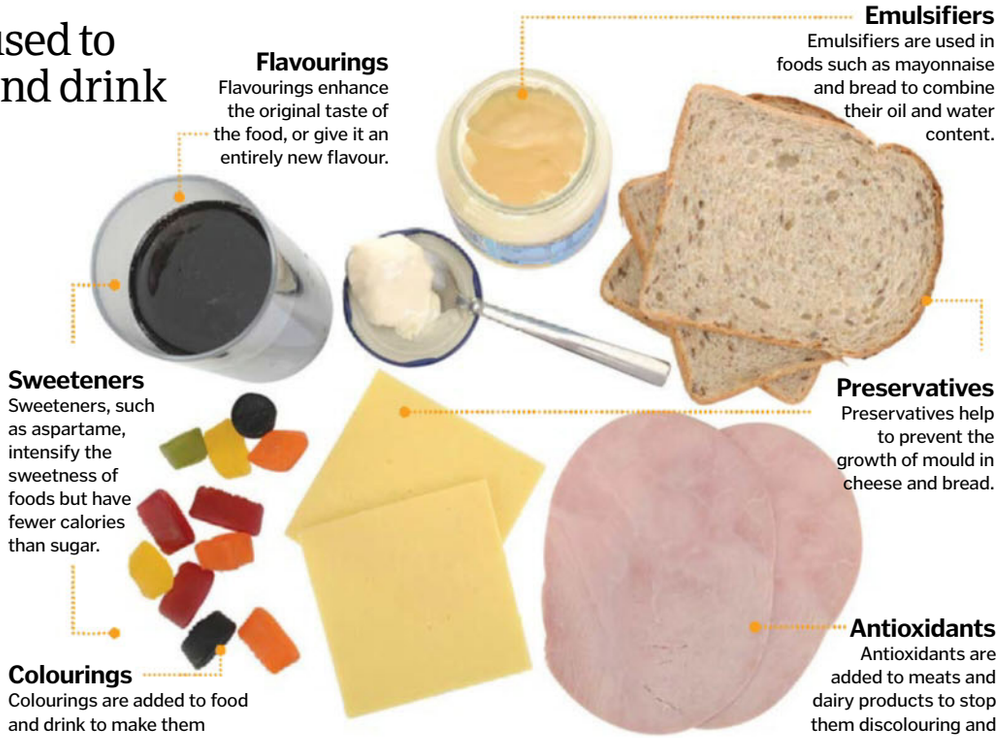
Learn how chemicals are used to enhance the taste of food and drink

You've probably noticed a long list of strange ingredients on your packets of food and drink, and it's likely that many of them are additives. Additives are chemicals added to processed foods and drinks, and each type serves a different purpose.

Antioxidants are used to extend the shelf life of food, slowing down the rate at which fats and oils react with oxygen, a process that causes food to go rancid and lose its original colour. Preservatives serve the same purpose, but instead prevent the growth of microbes that results in mould. Colourings, flavourings and sweeteners are used to improve the taste and appearance of many foods and drinks so that we are more likely to buy and enjoy them. Last, emulsifiers are used to help the oil and water in foods to mix, preventing them from separating as they would naturally do and making the overall appearance, structure and texture more appealing.

Food for thought

Where you can find common additives



Emulsifiers
Emulsifiers are used in foods such as mayonnaise and bread to combine their oil and water content.

Flavourings
Flavourings enhance the original taste of the food, or give it an entirely new flavour.

Sweeteners
Sweeteners, such as aspartame, intensify the sweetness of foods but have fewer calories than sugar.

Preservatives
Preservatives help to prevent the growth of mould in cheese and bread.

Colourings
Colourings are added to food and drink to make them appear more attractive.

Antioxidants
Antioxidants are added to meats and dairy products to stop them discolouring and going rancid.

Perfume chemistry

The science of scent explained

Traditionally, perfumes were created from natural ingredients, mixing essential oils extracted from plants such as lavender and rose to create enticing scents. However, nowadays we can artificially engineer aromas by creating pleasant-smelling chemicals known as esters. Esters are created when an alcohol reacts with an organic acid, with different combinations producing different smells. For example, when reacted with butanoic acid, the alcohol pentanol will create the pentyl butanoate ester, which smells of strawberries. By using chemicals, we can create fragrances that are not found in nature, or recreate scents that are otherwise difficult or expensive to obtain. The smell of perfume travels to our noses as the liquid evaporates off of the skin at room temperature.

Spraying perfume on warm areas of skin, such as your wrist and neck, will cause it to evaporate quicker

SAVE RHINOS NOW

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An animal in crisis
In eastern Africa, poachers use automatic weapons to slaughter endangered rhinos. The animals are shot and the horns are hacked away, tearing deep into the rhinos' flesh with the rhino left to die.

Make a difference today
Ol Pejeta is a leading conservancy fighting against this cruelty. It needs more funds so more rangers and surveillance can be deployed on the ground to save rhinos from this horrible treatment.

Join World of Animals
World of Animals magazine takes a stand against these atrocities and is proud to be in partnership with the Ol Pejeta Conservancy – 10% of our profits go towards saving rhinos in the fight against poaching

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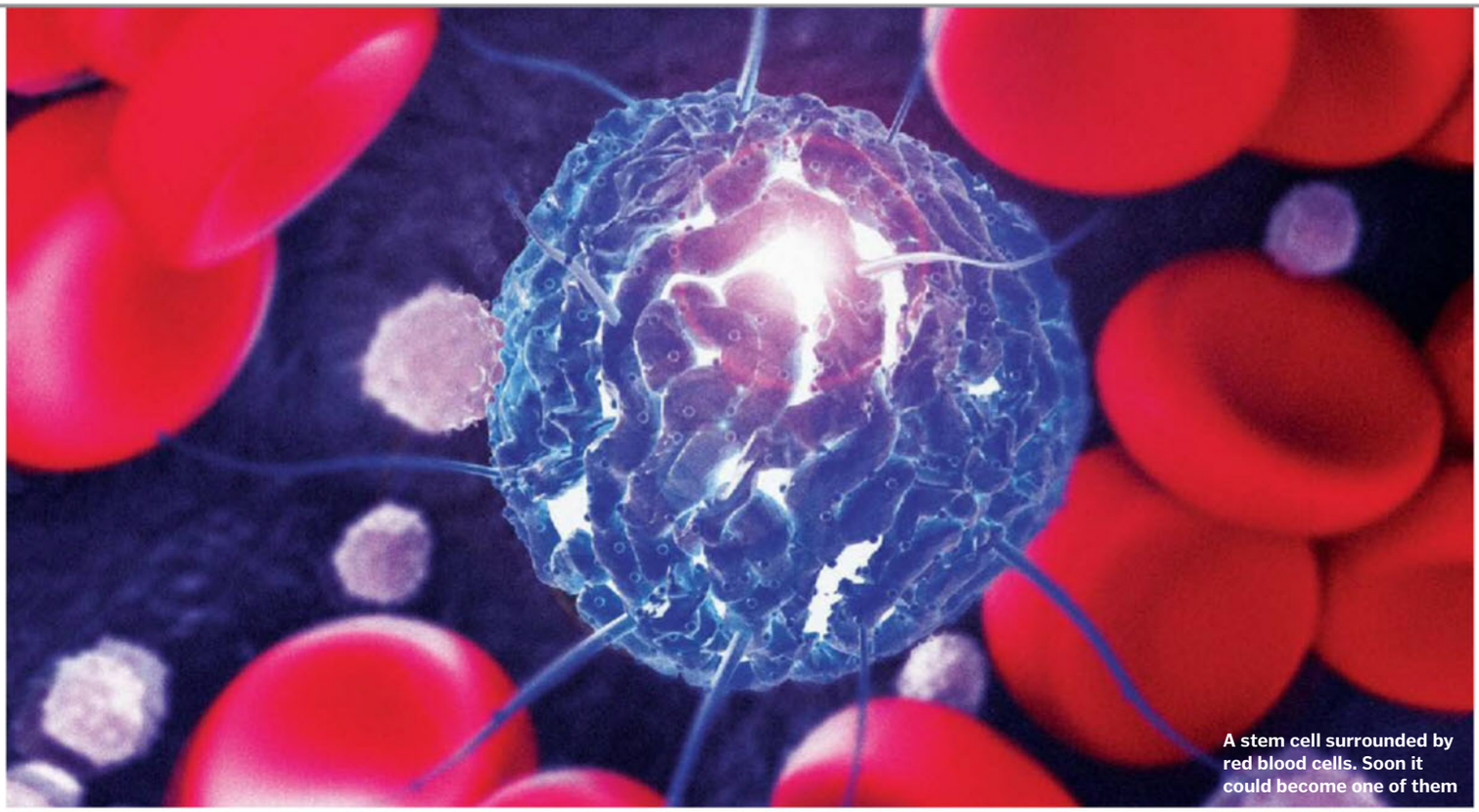
"Stem cells become specialised through a process called differentiation"



A stem cell surrounded by red blood cells. Soon it could become one of them

What are stem cells?

Understand how these building blocks bring new life

Stem cells are incredibly special because they have the potential to become any kind of cell in the body, from red blood cells to brain cells. They are essential to life and growth, as they repair tissues and replace dead cells. Skin, for example, is constantly replenished by skin stem cells.

Stem cells begin their life cycle as generic, featureless cells that don't contain tissue-specific structures, such as the ability to carry oxygen. Stem cells become specialised through a process called differentiation. This is triggered by signals inside and outside the cell. Internal signals come from strands of DNA that carry information for all cellular structures, while external signals include chemicals from nearby cells. Stem cells can replicate many times – known as proliferation – while others such as nerve cells don't divide at all.

There are two stem cell types, as Professor Paul Fairchild, co-director of the Oxford Stem Cell Institute at Oxford Martin School explains: "Adult stem cells are multipotent, which means they are able to produce numerous cells that are loosely related, such as stem cells in the bone marrow can generate cells that make up the blood," he says. "In contrast, pluripotent stem cells, found within developing embryos, are able to make any one of the estimated 210 cell types that make up the human body."

This fascinating ability to transform and divide has made stem cells a rich source for medical research. Once their true potential has been harnessed, they could be used to treat a huge range of diseases and disabilities.

Cloning cells

Scientists can reprogram cells to forget their current role and become pluripotent cells again – indistinguishable from early embryonic stem cells. These are called induced pluripotent stem cells (IPSCs) and can be used in areas of the body where they are needed, taking on the characteristics of nearby cells.

IPSCs are more reliable than stem cells grown from a donated embryo because the body is more likely to accept stem cells generated by itself. IPSCs can treat degenerative conditions such as Parkinson's disease and baldness, which are caused by cells dying without being replaced. The IPSCs fill those gaps, restoring the body's systems.

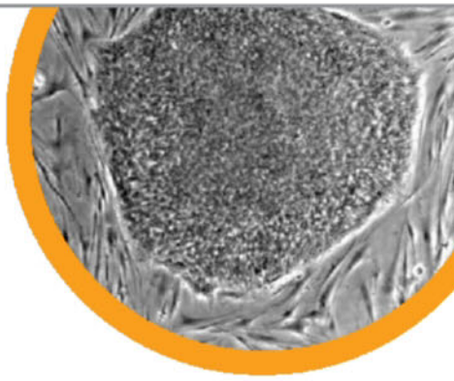
Professor Fairchild says IPSCs could help find a cure for certain disorders: "By deriving these cells from individuals with rare conditions, we are able to model the condition in the laboratory and investigate the effects of new drugs on that disease."

What happens if you halve a flatworm?

A It dies **B** It becomes two flatworms
C One half lives while the other dies

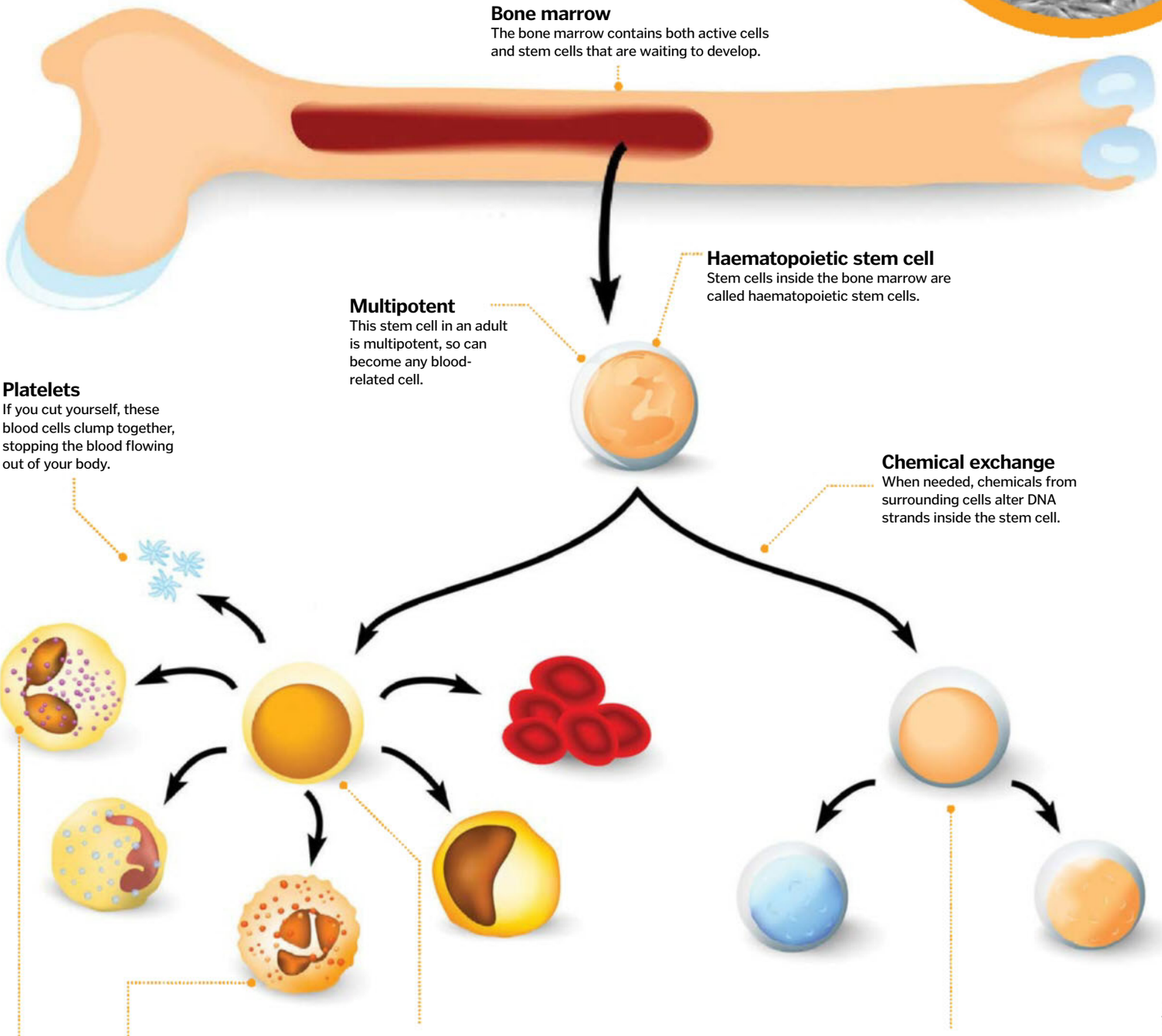
Answer:
Flatworms have the ability to regenerate organs, which is an invaluable skill for survival. Therefore, if you cut one in half, its pluripotent stem cells activate and create two flatworms. We'd rather you didn't try this, though!

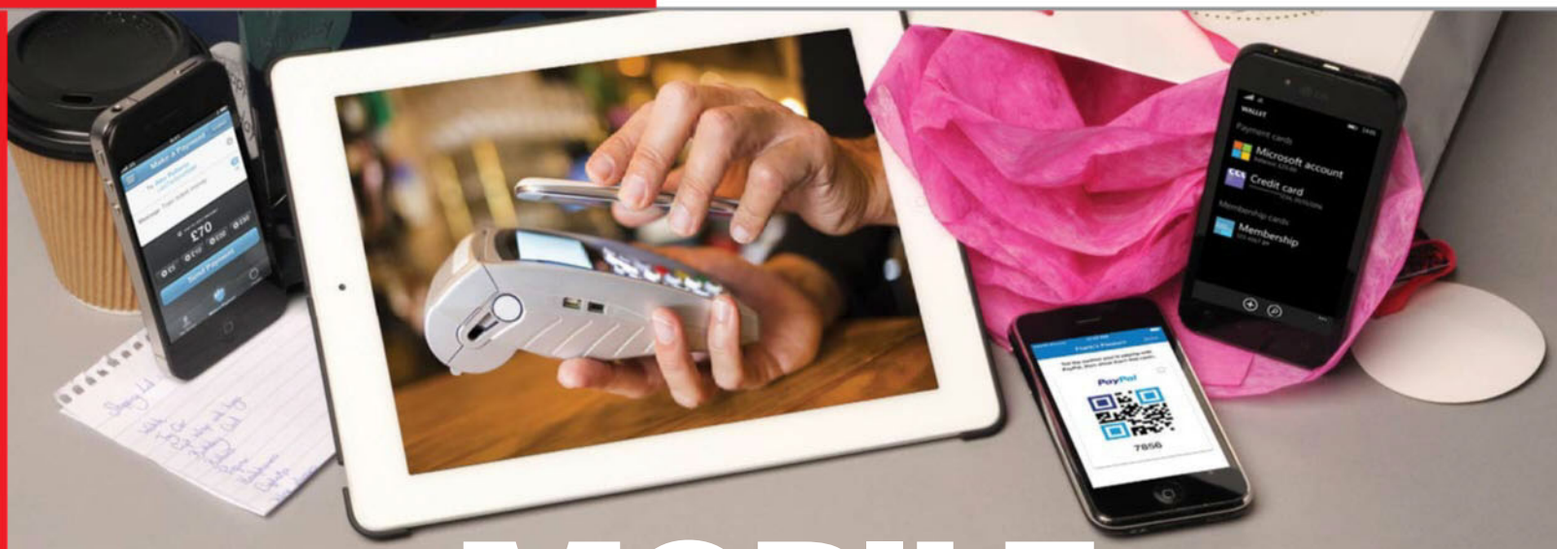
DID YOU KNOW? *Stem cells have been used to restore the sight of patients suffering from certain forms of blindness*



How to grow a stem cell

Fertilised human embryos that have been donated for research have plenty of stem cells inside them as the cells are yet to fully form. Scientists extract the cells and put them into a culture dish. This is filled with a culture medium, which is a mixture of nutrients that encourages the cells to divide and grow. As the cells divide they are placed into multiple dishes, each trying to complete an embryonic stem cell line. If a line is completed, it can then be used for further research and development.



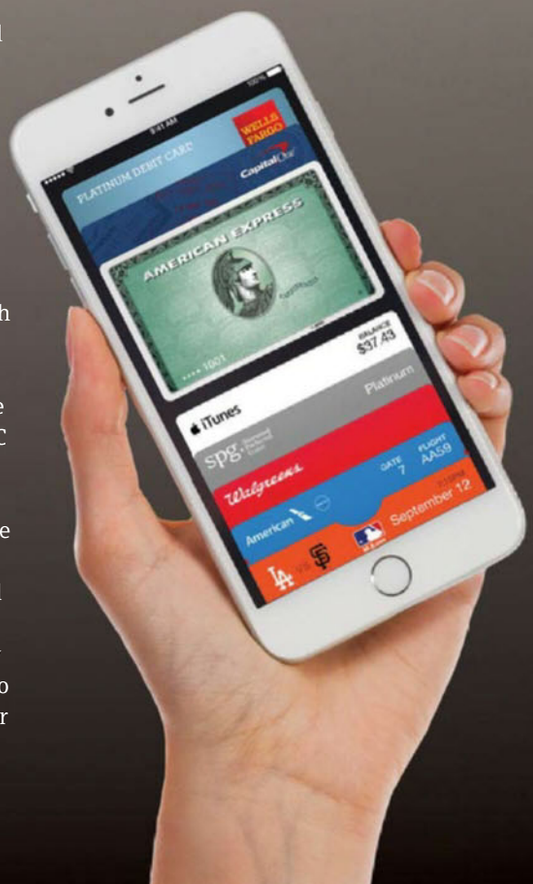


MOBILE PAYMENTS

Apple Pay and other touch technology that will revolutionise shopping

The pockets of today are more stuffed than ever before; straining under the weight of our smartphones, keys, cash, a plethora of credit and debit cards, loyalty cards, travel passes and more. Leaving the house with all of our essential items can sometimes feel like the cruellest memory test. Wouldn't it be a relief to be able to condense it all into one item that fits in the palm of your hand? Turns out, if you own a smartphone with a Near Field Communication (NFC) chip, perhaps you already can.

NFC is a set of wireless standards that enable portable electronic devices with dedicated NFC chips to 'talk' via short-range radio waves when held within a few centimetres of each other. This allows them to carry out a multitude of useful functions, including financial transactions, identification, access control and information transfer. Just as magnetic-strip plastic cards revolutionised the way we pay by eliminating the need to carry cash, NFC is set to transform our daily lives by freeing us from our wallets entirely.

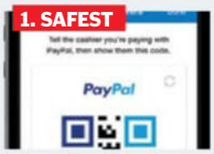


Even if you don't own an NFC phone, chances are you're already familiar with contactless technology. Cities all over the world use dedicated travel cards like London's Oyster, which can be topped up with credit in advance to save ticket-buying time and hassle at the turnstiles. In the last decade, all the major credit and debit card associations have added contactless payment functionality to their cards, allowing cardholders to settle small purchases by simply tapping their card on a payment terminal, removing the PIN verification stage altogether. Some transport services have even brought these two functionalities together, allowing travellers to abandon transport cards and instead pay their way through the turnstiles with contactless bank cards.

But where the contactless revolution is really beginning to gain traction is with NFC smartphones. Coupled with apps like PayPal and Google Wallet – which keep a virtual electronic track of the user's credit and debit cards, loyalty cards and gift cards – they can be

HEAD 2 HEAD
CURRENT CURRENCY

1. SAFEST



PayPal
Allows anyone with an email address to transfer funds to anyone else simply and safely, without sharing financial information.

2. SIMPLEST

Barclay's Pingit
Allows UK bank account holders to pay anyone with a UK mobile phone, even if the recipient doesn't use the app.

3. MOST INNOVATIVE

Square
A card-reader that converts any mobile device – owned by individuals right up to giant companies like Starbucks – into a point-of-sale merchant terminal.

DID YOU KNOW? *Oyster cards are used for over 20 million journeys on London's transport system every day*

NEAR FIELD COMMUNICATION

NFC isn't just for making payments. Check out all the amazing ways it can streamline our lives

Money transfer
PayPal's app enables people to transfer money to each other via NFC-enabled smartphones. This is separate from merchant payments and is designed for paying debts to friends and other PayPal and NFC users.

Tickets
Tickets for travel or events can be loaded onto smartphones at NFC payment terminals or online. Ticket inspection takes place by tapping the phone to an automatic gate or a handheld device carried by a conductor.

Online shopping
Computers and tablets using Intel's 4th Generation Core Processor give users the option to pay for their online shopping by tapping their NFC-enabled phone against their casing.

Boarding passes
Some European airlines send NFC boarding passes directly to passengers' smartphones so they can tap their mobile on dedicated readers at the airport. This works even if the phone's battery is dead.

Identification
NFC-enabled smartphones can replace traditional ID cards wherever an NFC reader is installed – turning your phone into your library card, your security key, your pass to clock in and out of work, and more.

Promotional codes
Advertisers can use NFC chips in promotional materials such as posters and stickers. When a smartphone is tapped against one of these chips, details of the deal load in the phone's web browser.

Security access
Hotels can send room access rights in advance to guests' NFC-enabled smartphones, allowing weary travellers to skip the physical check-in phase entirely and enter their room by simply tapping their phone to a reader on the door.

Timed medication
NFC medication labels embedded with prescription details can be loaded into patients' smartphones with the Quand app. The phone issues a reminder when it's time for a dose and requests a scan of the package as confirmation.

How Near Field Communication works

The technology is identical to that employed in contactless card payments, but the term NFC is generally used to refer to applications for smartphones. NFC devices fall into two categories: active and passive. Passive devices, like NFC tags or stickers, contain readable information but don't read any information themselves.

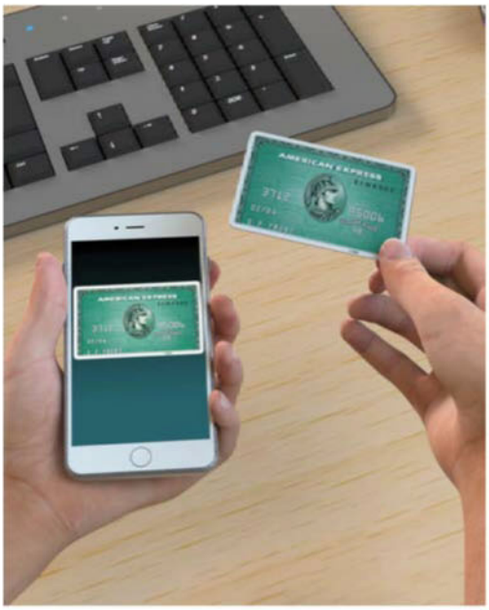
Active devices like smartphones and credit card readers have their own power supply and can read and transmit information, meaning that they can exchange data with other compatible devices. Two-way communication between a pair of active devices offers added payment security, as various requests and authentications are exchanged back and forth.

NFC works by short-range electromagnetic induction. The chip inside your phone is comprised of a secure microcontroller, protected memory, and a small antenna. When an electrical current passes through it, a magnetic field is set up, which in turn induces a current in the nearby device's chip. Data is exchanged via these electrical impulses.

"When using Apple Pay, their personal identity and card number are kept completely private"

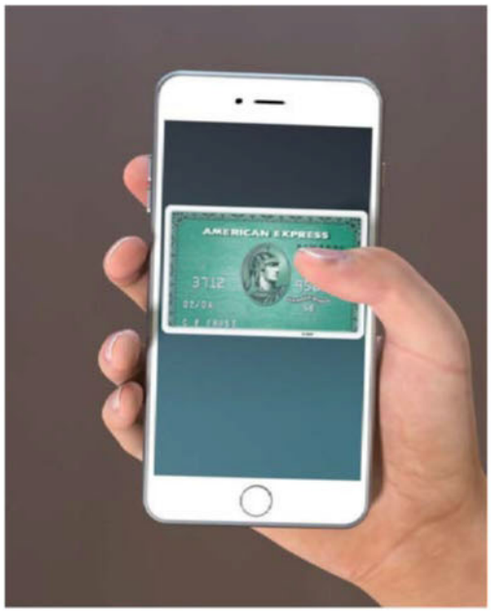
HOW APPLE PAY WORKS

Discover how the iPhone 6 combines NFC, Touch ID and built-in security



Loading payment cards

1 Cards are loaded into the iPhone's Passbook app either by scanning with the camera or by typing details in manually. Each new card must be confirmed separately with the issuing bank to activate payment information links.

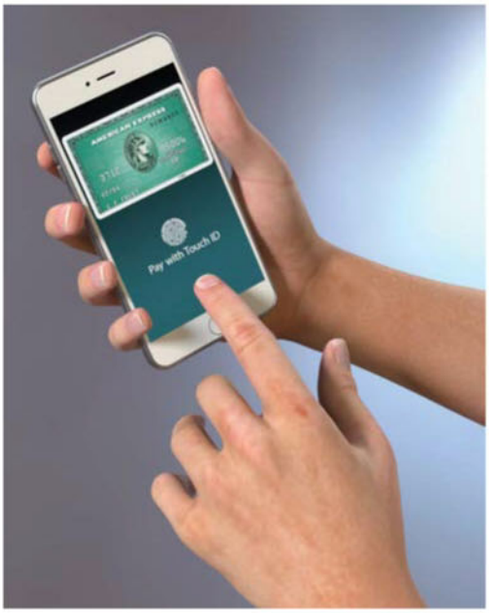


Selecting a card

2 To make a purchase, the shopper selects the card they want to use from within Passbook. Each stored card has been assigned a unique 16-digit Device Account Number, an encrypted token used in place of the real card number.

Identity protection

3 Unlike handing over a plastic payment card, when a shopper chooses to pay for their goods or service using Apple Pay, their personal identity and card number are kept completely private.

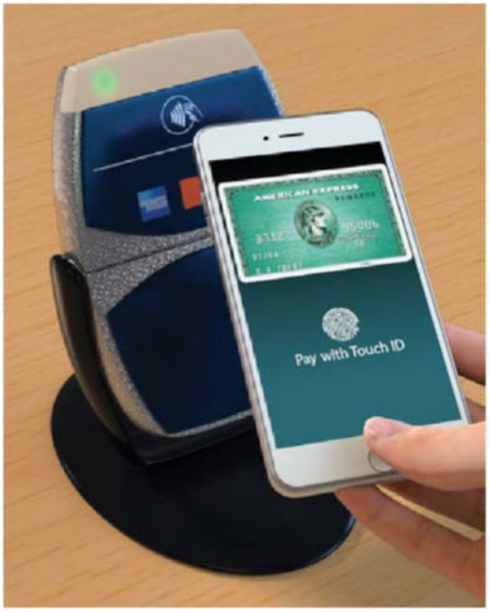


Authorising payment

4 The shopper taps their iPhone – with card selected – to the merchant's NFC payment terminal and authorises the payment by placing their finger on their phone's Touch ID fingerprint scanner.

Touch ID confirmation

5 Successful Touch ID authentication prompts the iPhone's Secure Element chip to release the card's unique Device Account Number, along with a transaction-specific dynamic security code that is used to process the payment.



Purchase completed

6 Confirmation that the transaction has been processed appears on screen and a subtle vibration and beep lets them know the transaction is complete. This is useful if the shopper has already pocketed their phone.

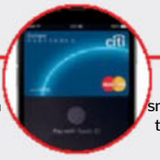
KEY DATES
CONTACTLESS EVOLUTION

1995
The Seoul Transportation Card is the first contactless smartcard to be used for electronic ticketing.

1997
ExxonMobil introduces SpeedPass, a contactless petrol payment system, and garners over 6 million users.

2003
MasterCard launches PayPass contactless payment cards – followed by American Express ExpressPay, Visa payWave and Discover Zip.

2011
Google and MasterCard team up to launch Google Wallet, an Android app that facilitates NFC smartphone payments.



2014
Apple Pay is the first smartphone payment system to combine NFC with Touch ID fingerprint scanning.

DID YOU KNOW? *Half of the world's mobile transactions take place in Kenya; M-Pesa provides millions with banking access*

ANATOMY OF A CONTACTLESS CARD TRANSACTION

Contactless lets you pay sums of up to £20 or $25 without entering your PIN

Energising
The card reader emits high-frequency radio waves, which energise the card by electromagnetic induction when it is brought within a few centimetres of the reader.

Radio connection
Embedded in the card, the contactless smart chip is wired to an antenna. Once the chip is powered on, a radio connection is established between the chip and the reader.

Encryption key exchange
The reader sends the card an encryption key, according to a private key known only to the card issuer. The card decrypts the key, allowing all future communication to take place using this key.

Transaction
The reader sends transaction details to the card, which uses another secret key – unique to the card – to generate an authentication code that authorises and exclusively identifies the transaction.

Completion
The card encrypts the transaction details with the card issuer's key before transmitting them to the reader; the reader returns a receipt to the card for storage.

used like contactless cards at the checkout (with PIN) transport hub, to swiftly pay for items online, and even allow individuals to transfer money instantaneously to one another by touching their compatible phones.

Yet despite these promises of speed, streamlining and simplicity, contactless payment hasn't really taken off. According to a 2014 survey by Thrive Analytics, although 78 per cent of respondents had heard of digital wallets like PayPal, only 32 per cent had ever used one. The main reasons they cited for their hesitance were concerns over security and the belief that – once you've pulled out your phone, unlocked it, accessed a payment app, and typed your PIN into the merchant's terminal – the time saving over traditional payment methods is overstated.

Learning to trust the safety of NFC payments may be just a matter of time and familiarisation. Indeed, once a connection has been established with a vendor's card reader, the steps used to process contactless payments are identical to those that process millions of magnetic-strip transactions securely every day. Contactless transactions have the advantage that the buyer's name and card number are kept completely private; the NFC chip encrypts all sensitive information before sending it, rendering it useless for any fraudulent transactions.

As for the second problem, Apple's newly launched Apple Pay app offers a neat solution: Touch ID fingerprint scanning. Once they've registered their cards and selected a default, Apple Pay users can authorise payments with just a single touch. Apple have a solid track record of dragging niche products firmly into the mainstream, and industry experts predict Apple Pay will have a game-changing impact on the uptake of mobile payments over the next year.

For businesses like OpenTable – an online restaurant-booking service that seats over 15 million diners per month at over 32,000 restaurants across North America, the UK, Japan and Germany – mobile payments represent an exciting new way to serve their customers. It removes the hassle of flagging down a member of a restaurant's waiting staff in order to settle the bill. The company rolled out its own mobile-payment scheme in San Francisco and New York in 2014, and one-touch Apple Pay offers a way to "make [the] payment experience even more intuitive and seamless", according to CEO Matt Roberts. Expect more businesses to follow suit in the near future.

"The roof cuts out 60 per cent of the natural light so 120 sports lights provide the correct lighting levels"

Under the Wimbledon roof

The technology that means rain no longer stops play

Tennis is a sport that requires good weather, so it's surprising that one of its premier competitions has been held in rainy England since 1877. So after 132 years and countless rain delays, a roof was built on Wimbledon's Centre Court for the 2009 Championships. The primary function is to keep water off of Centre Court so games can continue when a downpour begins, but it also means games can continue after dark.

The roof spans 5,200 square metres (56,000 square feet) and is made up of a translucent membrane held up by ten steel trusses, each weighing around 70 tons.

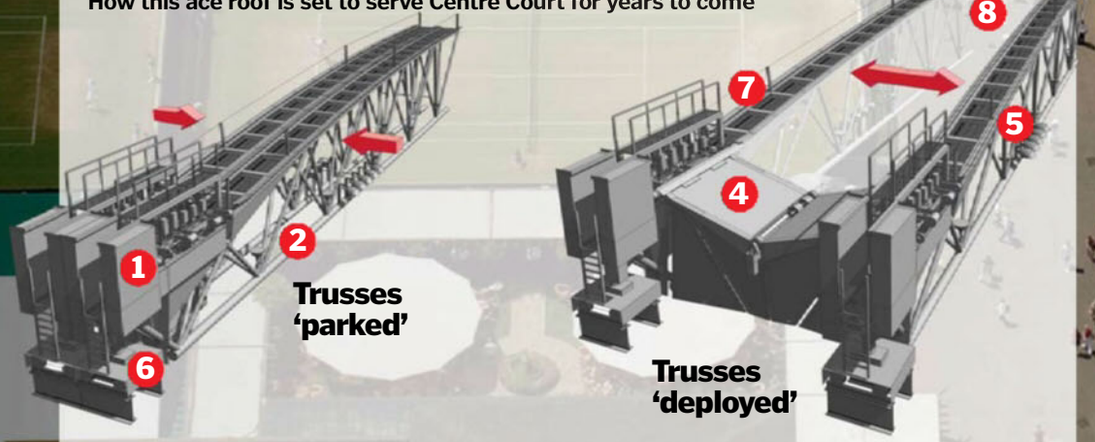
John Biggin was project manager of the build and explains how the roof closes: "The whole system is electrically powered. Actuators push on V-shaped arms, which flatten out, pushing each truss apart. These run on bogies, spreading along rails until the roof is covered."

It only takes around eight minutes to close but the lights and air management system take up to half an hour to get working. The roof cuts out 60 per cent of the natural light so 120 specialist sports lights are used to provide the correct lighting levels required for both the match and the television broadcasts. The air-conditioning system regulates the temperature and removes moisture from inside the stadium so conditions are as similar to a roofless atmosphere as possible.

"The main challenge was the design," says Biggin. "We used the concertina because of space restrictions but we built a model at Sheffield so we knew it worked. It's the only one in the world." The Wimbledon roof has revolutionised one of the world's most famous sporting events by allowing matches to go on long after dark or while the traditional rain is lashing down all around.

Up on the roof

How this ace roof is set to serve Centre Court for years to come



1 Control gear boxes
These gear boxes operate the actuators.

2 Trusses
Each of the ten steel trusses that span the court weighs 70 tons.

3 Actuators
Electronic actuators push down on the arms between the trusses.

4 Arms
As the arms are pushed, they spread the trusses apart, closing the roof.

5 Lights
120 sports lights are carefully arranged so the court is evenly lit.

6 Bogies
The trusses run on these wheeled trolleys that run along a rail.

7 Locking arms
Arms across the top of the roof lock in place to withstand wind and rain.

8 Time
It takes between eight and ten minutes for the roof to close.

THE STATS
GAME, SET, STATS

TOTAL WEIGHT 3,000 tons

WIDTH 77m

LENGTH 65m

BUILT 2009

CLOSING TIME 8-10 mins

LIGHTS 120

DID YOU KNOW? *Amelie Mauresmo and Dinara Safina were the first players to play under the new Centre Court roof*

Incredible retractable roofs

Rogers Centre, Toronto

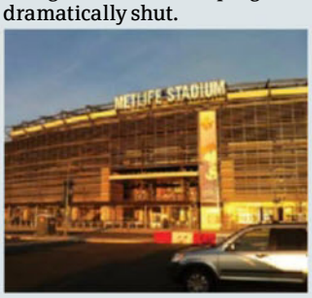
When it was finished in 1989, the Rogers Centre became the first sports stadium in the world to have a retractable roof. Constructed from four huge steel panels, the 11,000-ton roof slides away in just 20 minutes.

Rod Laver Arena, Melbourne

The venue for the Australian Open final has a retractable roof, vital for a venue that experiences scorching temperatures and lashing rain. The rust-proof roof takes 20 minutes to shut, rolling over the court on arched trusses at 1.3 metres (4.3 feet) per minute.

New Atlanta Stadium, Atlanta

The proposed new home of NFL team Atlanta Falcons will sit beneath a mind-boggling roof. It will close like a camera lens, its eight sections swooping dramatically shut.



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TRUSTPILOT

Model shown:
ICON-300RS

1. OLDEST

View camera
View cameras were the first to offer tilt and shift capabilities as the lens in those cameras was mounted on flexible bellows.

2. NEWEST

Pro lenses
Modern-day versions can be mounted on DSLRs and offer the latest technology for accurate tilt and shift effects, but they are expensive.

3. MOST FUN

Lensbaby
You can achieve fun tilt and shift effects with more affordable kit too. Lensbaby offers a range of Composer Pro lenses with tilt and shift effects.

DID YOU KNOW? *Traditional-view cameras have tilt and shift capabilities built in as the lens is mounted on adjustable bellows*

Tilt and shift lens

How to alter perspective and turn a standard scene into a toy town

There are a wide variety of photography lenses out there that are designed for specific genres, such as macro lenses for close-ups, wide-angle lenses for landscapes and telephoto lenses for wildlife. Tilt and shift lenses, however, are considered pretty specialist and for good reason. These lenses are commonly used by professional photographers who want to eliminate the possibility of optical distortions when photographing architecture or even landscapes.

Unlike standard lenses, tilt and shift lenses can be physically manipulated in order to adjust the plane of focus and perspective within an image. Tilt and shift are also two separate adjustments, both of which can affect a photo in different ways.

Tilting the lens left, right, up or down changes the angle of the lens relative to the camera body, which gives you more control over depth of field, so you're able to determine how much of the image appears in focus. Tilting is often used by pros to put the entire scene in focus, from front to back, or to create the popular miniature photo effect, which essentially makes depth of field much more shallow.

On the other hand, shifting the lens up, down or from side to side enables you to include objects within the photo currently outside the field of view, without having to tilt or move the camera body itself. This means you can photograph tall structures from the ground in their entirety by shifting the lens upward so that the top of the structure comes into view. This also prevents optical distortions such as converging verticals, where a building appears to lean backward due to vertical lines leaning in.

The toy town effect

A popular tilt and shift lens effect is turning a standard scene into a miniature toy town. This effect is possible thanks to the lens's ability to tilt the plane of focus, meaning you can control the depth of field. By pointing the camera down and tilting the lens up, the focal planes in front and behind the subject you want to appear sharp, are thrown out of focus. The blurred areas now replicate a very shallow depth of field you would only otherwise see in close-up macro photography, hence why the scene appears much smaller than it actually is.

How shift works

Using the shift effect can help you fit much more in a frame

Converging verticals

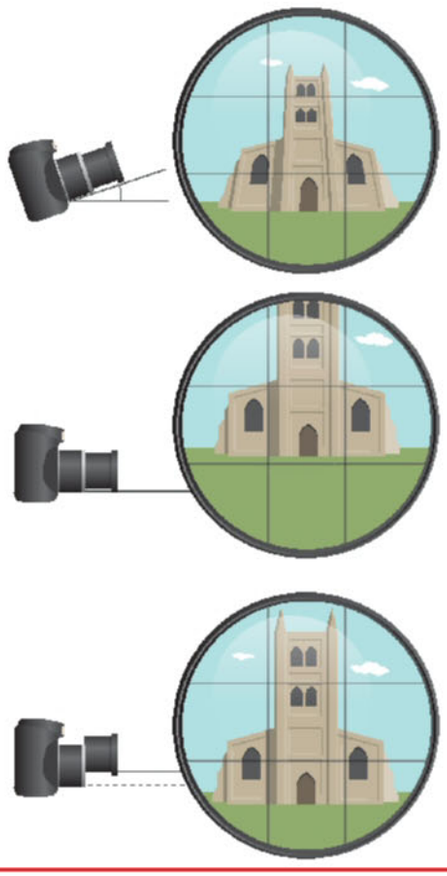
When photographing a structure using a standard lens you have to point the camera upward to include the top and bottom of the building. This will distort the perspective result in converging verticals.

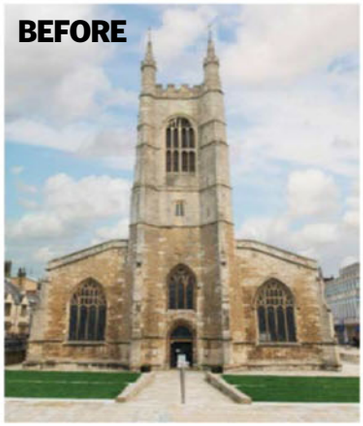
Standard lenses

To avoid this with a standard lens, you would need to keep the camera level and shoot face-on to the structure. But shooting tall buildings from the ground means it would be impossible to capture the entire structure within your shot.

Tilt and shift effect

A tilt and shift lens enables you to keep the camera face-on to your subject and use a vertical shift movement to capture the entire structure without distortions. As the lens has a larger image circle, it's possible to incorporate more within the frame.





A standard lens creates converging verticals, but a tilt and shift lens avoids this

"The polish contains fine iron filings, which respond to the magnet during the drying process"

The science behind magnetic nail varnish

Discover how physics meets fashion in the latest beauty must-have

Magnetic nail polish is one of the hottest trends in the beauty business right now and those who take pride in having perfectly manicured paws are all for this latest innovation. Combining physics and fashion, magnetic nail polish produces unique three-dimensional patterns when it comes into contact with the supplied magnet on the lid. The polish itself contains fine iron filings, which respond to the magnet during the drying process. In fact, the filings themselves turn into miniature bar magnets when under the influence of a magnetic field, because they contain highly mobile electrons. It's because of this that patterns will emerge, as each fine piece of metal has a south and north pole, so they align themselves with the magnetic field lines of the original magnet. The shape and force of the magnet on the lid will also vary results, so it's possible to get some really unique nail-art effects.

Laws of attraction

Understanding magnetic nails with bar magnets

Attracting poles
Iron filings are ferromagnetic, which means they become miniature bar magnets when under the influence of a magnetic field.

Repelling magnets
Magnetic poles that are the same will repel one another and opposites attract, so some iron filings will be forced away from the magnet. This helps to create a distinct pattern.

Magnetic field
Every magnet has a magnetic field surrounding it, which will affect some metals, in this case iron filings. The filings form a pattern as they line up in the direction of the magnetic field lines.

Ionic hair dryers

Is there real science behind the latest buzzword in hair care?

Hailed as the latest hair-care must-have, new ionic hairdryers promise to tame frizz-prone tresses, but how do they work?

Many modern conditioning products contain chemicals that give the hair a positive charge. Friction from brushing and straightening can have the same effect as electrons are removed from the strands. If this unbalanced charge isn't neutralised the hair can easily become a static mess. To battle this, inside an ionic hairdryer is an electrode that produces negative ions. A mineral called tourmaline is often used as it is pyroelectric, which means it emits these ions when heated. The ions are then blown across the hair once the dryer has been switched on. These negative ions balance out the positive charge, so you end up frizz-free with a sleeker style.

THE STATS
APPLE FACTS

1976 YEAR FORMED
FIRST IPOD 2001
AMOUNT OF IOS DEVICES SOLD 800 million
2013 REVENUE $170.9 billion
435 APPLE STORES WORLDWIDE
APPS IN THE APP STORE 1.2 million

DID YOU KNOW? *Pixel density is the number of pixels in a fixed area. Resolution is the pixels over the width and height of a device*

Retina HD displays

Is Apple's invention better than its counterparts?

In today's world of smartphones and tablets, a top-notch display is essential to watch the latest Vine or check out Instagram updates. Since 2010 Apple's iPads and iPhones have used a Retina display, which was considered by many to be the finest screen type on the market. After being upstaged by the likes of 4K and 1080p resolutions, it has now made a comeback in the form of Retina HD.

Apple claim that this new version of Retina fools the human eye into thinking that it is looking at a real object rather than a picture on a screen. This is due to the incredibly high pixel density, meaning the brain can't distinguish between individual pixels. At 401ppi (pixels per inch) the screen of the new iPhone 6 Plus is reportedly the sharpest display available.

The Retina HD display also uses IPS (in-plane switching). This allows the LCD to be seen from a much wider range of angles than a regular screen. The downside to it is that the new display uses up a lot of precious battery and compatible apps take up much more of your device's space. Essentially, if an image looks better under Retina HD, it will take up a whole lot more space, for better or worse. So make sure pictures of your cats are kept to a manageable amount on your new iPhone!

Apple products that use Retina display technology produce images that are clear and crisp

History of the Retina display

401 PPI
iPhone 6 Plus
The first to contain a polarized layer to reduce reflections

326 PPI
iPod Touch / iPhone 4, 4s, 5c, 5s, 6
Twisted nematic LCDs became IPS to reduce glare

264 PPI
iPad Air
The same resolution as the iPad mini 3

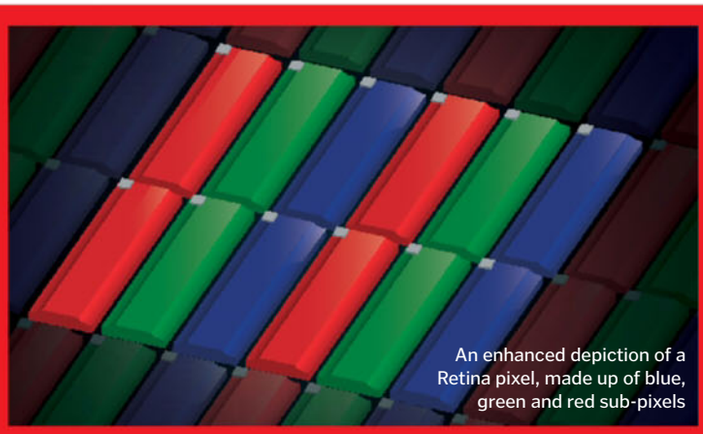
227 PPI
MacBook Pro (3rd generation)
MacBook needs fewer PPI as it's viewed from further away

How do pixels work?

The golden rule is the more pixels you have, the sharper the display. Pixels are made up of red, green and blue sub-pixels and signals in a device tell each when to light up. In its Retina display, Apple uses Super High Aperture (SHA) technology, which places a layer of resin between the pixels and signal lines. The pixels are so tightly packed in this system that the resin is needed to keep everything in order.

A possible downside to Retina technology is that the more pixels you squash in, the more likely they are to cause interference with each other and affect the image. SHA helps avoid this. Apple believes that a person cannot differentiate between individual pixels from one of their Retina HD devices at a normal viewing distance – around 25 centimetres (ten inches) for an iPhone and 38 centimetres (15 inches) on an iPad.

It remains to be seen whether technology companies can keep pumping in pixels or whether a maximum level will be reached in the next few product generations.



An enhanced depiction of a Retina pixel, made up of blue, green and red sub-pixels

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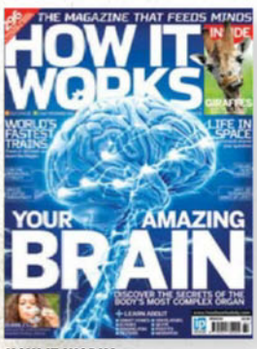

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5 TOP FACTS IN YOUR EYES

Blue eyes
1 People with blue eyes all share a common ancestor. A genetic mutation about 10,000 years ago gave someone blue eyes, when everyone else's were brown.

Blinking
2 Your eyes will blink around 15-20 times per minute and it last for around 100 milliseconds. You also blink more when talking than when reading.

Sight
3 Technically, you see with your brain and not your eyes. Poor vision sometimes stems from problems with the visual cortex of the brain and not the eye itself.

Tears
4 Tears are not only an emotional response; they also help prevent your eyes from drying up and get rid of any irritating particles that could cause damage.

Measurements
5 On average, a human eyeball is around 2.5cm (1in) in diameter and weighs as little as 7.5g (0.25oz). A giant squid's eyeball is ten times as big as a human's.

DID YOU KNOW? *SAD is more common in women and people between the ages of 15 and 55*

Dilating eye drops

Discover how they are used to diagnose and treat eye conditions

Our eyes need good care to stay healthy

Sight is one our most important senses, so maintaining good eye health is absolutely essential. However, eyesight problems can be difficult to detect or treat on the surface, so specialist eye doctors will often use dilating eye drops in order to get a better look inside the eye at the lens, retina and optic nerve.

The drops contain the active ingredient atropine, which works by temporarily relaxing the muscle that constricts the pupil, enabling it to remain enlarged for a longer period of time so a thorough examination can be performed. Some dilating eye drops also relax the muscle that focuses the lens inside the eye, which allows an eye doctor or optometrist to measure a prescription for young children who can't perform traditional reading tests.

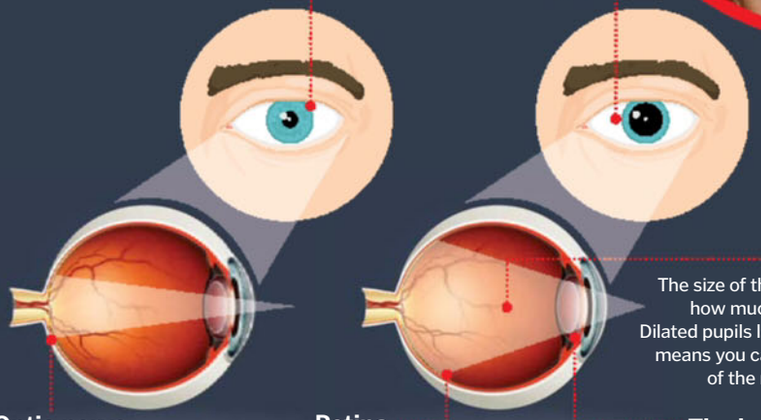
Dilating eye drops are not only used to help perform procedures, they may also be administered after treatment, as they can prevent scar tissue from forming. They are also occasionally prescribed to children with lazy-eye conditions, as they will temporarily blur vision in the strong eye, causing the brain to use and strengthen the weaker eye.

Before and after

A better look inside the eye

Contracted pupil
A contracted pupil will appear much smaller and let less light into the eye, which makes it difficult to see the retina and optic nerve inside.

Dilated pupil
Dilating eye drops will temporarily paralyse the muscle that constricts the pupil, which means the pupil will remain dilated for much longer.



Ray of light
The size of the pupil will determine how much light enters the eye. Dilated pupils let in more light, which means you can see a larger portion of the retina and optic nerve.

Optic nerve
The optic nerve carries electrical impulses from the retina to the brain, which then interprets them as visual images.

Retina
This light-sensitive tissue converts incoming light into electrical impulses. These impulses are then sent to the optic nerve.

The lens
It is positioned behind the pupil and helps focus light onto the retina. Some dilating eye drops relax the muscle around it to prevent the lens from focusing.

How mood-lifting lamps work

Can these specially designed light bulbs enhance mood, appetite and sleep?

We can all be prone to a touch of the winter blues when the long nights roll in, but for some it's a condition that can last throughout the season, affecting their mood, sleep and eating patterns. The medical definition is SAD, or seasonal affective disorder, and it's a type of depression.

However, light therapy has been clinically proven to elevate some sufferers' symptoms. It requires patients to sit under specially adapted fluorescent lamps, which replicate the effect natural sunlight has on the body. Unlike standard light bulbs, which have a brightness power of around 200 lux, sunlamps emit a more intense light source at around 2,500 lux, with a full spectrum of colour. With similar properties to daylight, sunlamps can help regulate your body clock and balance important chemicals and hormones, which improve our mood.

SAD lights are designed to make you feel like your usual bright self

History of the universe

The universe was born in a flash nearly 14 billion years ago. Discover what's happened since then...

13.8 BILLION YEARS AGO

0 seconds

The Big Bang

1 The moment the universe was created is called the Big Bang. Nobody knows how or why, but astronomers know the universe is expanding today, so at some point everything must have been closer – a lot closer! One mistake people make is thinking of the Big Bang as an explosion into space, when there was nothing for it to explode into. Everything came into the existence in the Big Bang.

10^{-43} to 10^{-36} seconds

The Grand unification epoch

2 Today we have four fundamental forces: the strong force, the weak force, gravity and the electromagnetic force. But back in the Big Bang, conditions were so unimaginably extreme that three of these four forces – all of them except gravity – were unified as one single force. When physicists talk about finding a Grand Unified Theory, this is what they mean. Gravity had separated from the other forces before this epoch.

10^{-36} and 10^{-32} seconds

Inflation

3 Today, one side of the visible universe looks pretty much like the other. For this to be the case opposite sides of the visible universe must have been in close contact to share their characteristics, but today they are so far apart that light has not had time to travel from one side to another. The answer – possibly – is a period of incredible expansion called inflation, which blew the universe up faster than the speed of light.

5 TOP FACTS
UNIVERSAL MATTERS

Dark matter
1 This mysterious substance makes up about 84 per cent of all the matter in the universe, even though we still do not know what dark matter is.

Hydrogen
2 The other 16 per cent is matter we can see. The most common element is hydrogen, accounting for 75 per cent of all 'normal' matter. It's mostly found in giant gas clouds.

Stars
3 There are an estimated 200-400 billion stars in our own galaxy and there could be as many as a trillion trillion stars (10^{24}) in the entire visible universe.

Planets
4 Astronomers have discovered more than 1,800 extra-solar planets so far, but it is believed that there could be at least as many as 100 billion planets in our galaxy alone.

Galaxies
5 The most common larger-scale objects are the galaxies themselves, of which there could be as many as 200 billion in the visible universe.

DID YOU KNOW? *The most distant object ever seen is a gamma-ray burst, a massive star that exploded 13.14 billion years ago*

200 million years

The first stars

6 The first stars were enormous, possibly as much as a thousand times more massive than the Sun, and they were vital in the history of the universe in heating and ionising the hydrogen gas around them. Inside these stars, new elements were created, before being released into the universe to be recycled into new stars and – eventually – planets. The first stars exploded as supernovas.

380,000 years

Cosmic microwave background radiation

5 It took another 380,000 years for temperatures in the universe to drop below about 3,000 degrees Celsius (5,432 degrees Fahrenheit), which is cool enough for electrons to attach themselves to atomic nuclei. Until this time photons of light were continually absorbed or scattered by the fog of free electrons, so light could never travel far. When the nuclei soaked up the electrons, light suddenly found it could travel unhindered. This is the same light we see today, stretched by the expansion of the universe, as the so-called cosmic microwave background radiation.

3-20 minutes

Creation of atoms

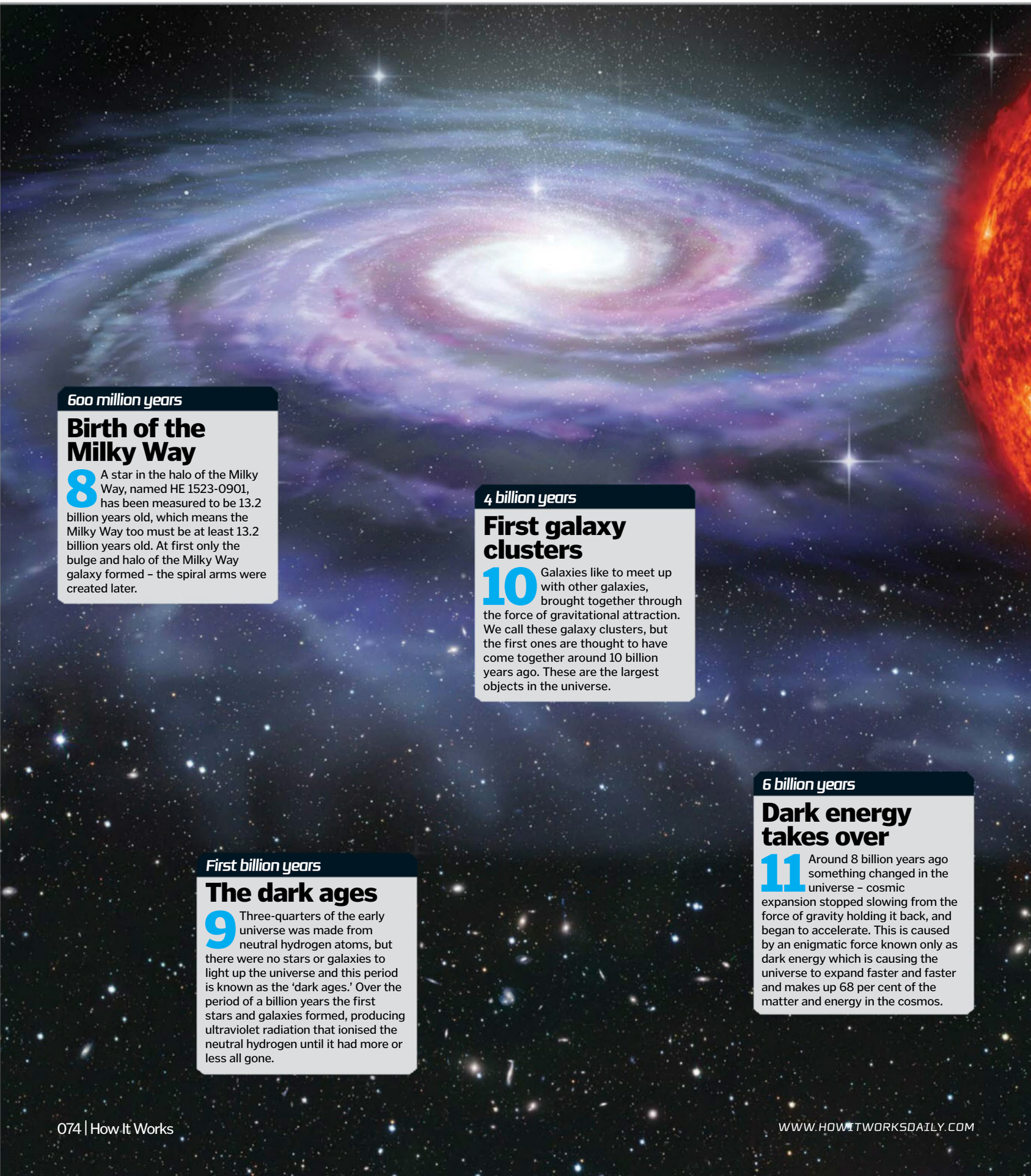
4 After the first three minutes in the universe's already eventful life, it was a raging, chaotic sea of protons, electrons and neutrons. As the universe continued to cool down, the protons and neutrons were able to combine to form simple atomic nuclei, mostly hydrogen, some helium and a smidgen of lithium. This process is called nucleosynthesis. It was still too hot for electrons to join them at this point, though.

500 million years

The first galaxies

7 When the first stars exploded, they left behind black holes, which merged and grew larger. Around these black holes more and more gas began to gather and a system of stars would form. These were the first galaxies, just a few hundred light years across but densely packed with star formation. These proto-galaxies would then merge with each other to build into the larger galaxies we see today.

"Our Sun and the Solar System are only about a third of the age of the universe"



600 million years

Birth of the Milky Way

8 A star in the halo of the Milky Way, named HE 1523-0901, has been measured to be 13.2 billion years old, which means the Milky Way too must be at least 13.2 billion years old. At first only the bulge and halo of the Milky Way galaxy formed – the spiral arms were created later.

4 billion years

First galaxy clusters

10 Galaxies like to meet up with other galaxies, brought together through the force of gravitational attraction. We call these galaxy clusters, but the first ones are thought to have come together around 10 billion years ago. These are the largest objects in the universe.

6 billion years

Dark energy takes over

11 Around 8 billion years ago something changed in the universe – cosmic expansion stopped slowing from the force of gravity holding it back, and began to accelerate. This is caused by an enigmatic force known only as dark energy which is causing the universe to expand faster and faster and makes up 68 per cent of the matter and energy in the cosmos.

First billion years

The dark ages

9 Three-quarters of the early universe was made from neutral hydrogen atoms, but there were no stars or galaxies to light up the universe and this period is known as the 'dark ages.' Over the period of a billion years the first stars and galaxies formed, producing ultraviolet radiation that ionised the neutral hydrogen until it had more or less all gone.

THE STATS AROUND THE UNIVERSE

AGE 13.82 billion years

DIAMETER OF OBSERVABLE UNIVERSE **93 billon light years**

NUMBER OF GALAXIES 100-200 billion

NUMBER OF ATOMS 10^{78} to 10^{82}

RATE OF COSMIC EXPANSION 74km /sec/ megaparsec

TEMPERATURE -270 °C

DID YOU KNOW? *The visible universe isn't everything – there is a lot more, but it's so far away that its light has not reached us yet*

5.2 BILLION YEARS FROM NOW

19 billion years

Death of the Sun

14 The Sun will not last forever. One day it will have used up all its hydrogen fuel for producing energy by nuclear fusion, and will die by first expanding into a red giant that will swallow the inner planets, including Earth. Then the Sun's expanded outer layers will break away from the Sun to form a new planetary nebula. All that will be left of the Sun will be its white hot core, a white dwarf.

9.24 billion years

Birth of the Sun

12 Our Sun and the Solar System are only about a third of the age of the universe. They were formed when a cloud of gas collapsed into a star; a disc of gas and dust began to circle the newborn Sun and eventually coalesce into the planets, including Earth.

13.82 billion years

Present day

13 The universe today is a very different place to the universe just after the Big Bang. Matter has been organised into planets, stars and galaxies. The galaxies are all moving away from one another at a constantly accelerating rate. The Sun is midway through its life and Earth will remain habitable for a few billion years more before the Sun grows too hot.

The fate of the universe

After the question 'where did the universe come from', the next big question on everybody's lips is: 'what will happen to it in the future?' There are several possibilities and it comes down to which force will win out: gravity, or dark energy? If dark energy stops expanding the universe, the gravity of all the galaxies and dark matter could cause it to begin to contract again, possibly all the way down to a single point, causing another Big Bang. Alternatively, there might not be enough matter to stop the expansion of the universe and everything would continue to drift apart, slowing but never stopping. If this happens, eventually after trillions of years all the stars will die and atoms will decay and the universe will be dark forever. The worst-case scenario is that dark energy will increase the universe's rate of expansion, pulling galaxies, stars, planets, even the universe itself, apart in a so-called Big Rip.

"The astronaut's chunky backpack carries the primary life support subsystem..."

Inside a spacesuit

What's so special about an astronaut's outfit that it can keep them alive in space?

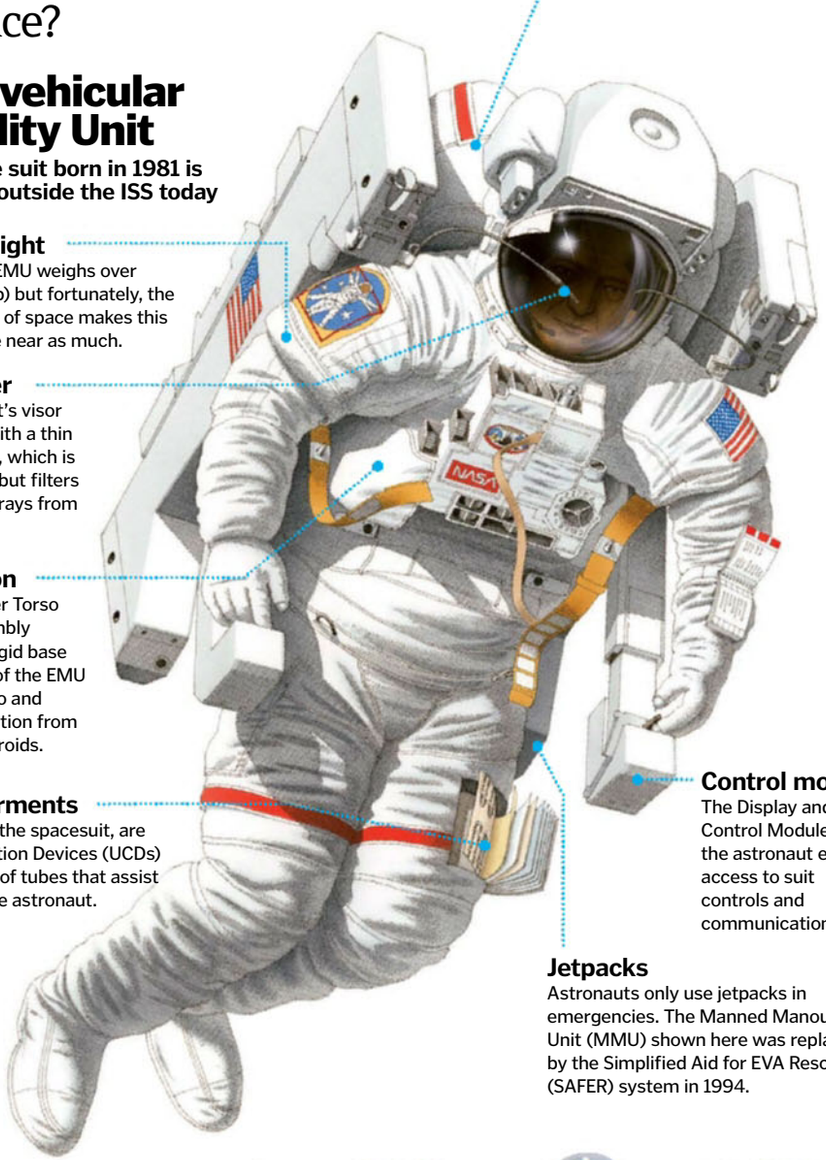
It's probably best to think of a spacesuit not as an item of clothing – like a jumper you'd put on when it's cold or a pair of wellies to keep your feet dry – but as a habitat or a small personal spaceship astronauts wear. Two of the main threats to human life in space are the lack of oxygen and the extreme range of temperatures, which can fluctuate from below -100 degrees Celsius (-150 degrees Fahrenheit) to in excess of 120 degrees Celsius (242 degrees Fahrenheit). But they can face other dangers, too: the extremely low pressure, micrometeorites travelling several times the speed of a bullet and exposure to high levels of radiation, unfiltered by any planetary atmosphere like Earth's, travelling from the Sun and deep space.

Astronauts need protection from these dangers while on an extravehicular activity (EVA) in space, so the modern spacesuit is designed to do just that. The outer section is divided into several main pieces with flexible and rigid parts, designed to provide mechanical protection from impact and a pressurised, oxygenated environment within the suit.

Underneath that, the astronaut wears a garment that helps regulate their body temperature with tubes that are woven into it, inside which water circulates for cooling. The astronaut's chunky backpack carries the primary life support subsystem, which pumps the oxygen into the astronaut's helmet for them to breathe and 'scrubs' the excess carbon dioxide out of the air they exhale. It also holds the electricity supply required to run the suit's systems and a water tank for the cooling system.

Extravehicular Mobility Unit

The space suit born in 1981 is still used outside the ISS today



Life support
The heavy backpack contains power for the spacesuit, air and a water tank for cooling.

Heavyweight
A complete EMU weighs over 100kg (220lb) but fortunately, the microgravity of space makes this feel nowhere near as much.

Gold layer
An astronaut's visor is covered with a thin layer of gold, which is transparent but filters out harmful rays from the Sun.

Protection
A Hard Upper Torso (HUT) assembly provides a rigid base for the rest of the EMU to connect to and some protection from micrometeoroids.

Undergarments
Underneath the spacesuit, are Urine Collection Devices (UCDs) and a series of tubes that assist in cooling the astronaut.

Control module
The Display and Control Module gives the astronaut easy access to suit controls and communication.

Jetpacks
Astronauts only use jetpacks in emergencies. The Manned Manouvering Unit (MMU) shown here was replaced by the Simplified Aid for EVA Rescue (SAFER) system in 1994.

The Z-suit

NASA's prototype Z-suit is a work in progress on an update to the current incarnation of the spacesuit, whose basic structure has been used for 30 years, ever since the Extravehicular Mobility Unit (EMU) was first made in 1981. At a glance, it doesn't look radically different to contemporary space suits, but it's been designed to include several key features that will allow it to be used in both the microgravity of space and for future missions to planets such as Mars, which the Apollo-era spacesuit isn't capable of. It can be quickly put on and taken off (current spacesuits can take an hour or more to put on) and include a suitport dock, which replaces the airlock on a spacecraft. This means the spacecraft and space suit would be kept at the same pressure, so astronauts wouldn't need to pre-breathe oxygen for at least 30 minutes before an EVA as they do now to prevent decompression sickness. The Z-2 prototype should be completed by the end of 2014.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Watch a large solar flare recorded in August 2014

www.howitworksdaily.com

DID YOU KNOW? *Space weather can play havoc with electronics on Earth, which is why scientists have space-weather forecasts*

Rings of Saturn

How the gaps in Saturn's rings formed

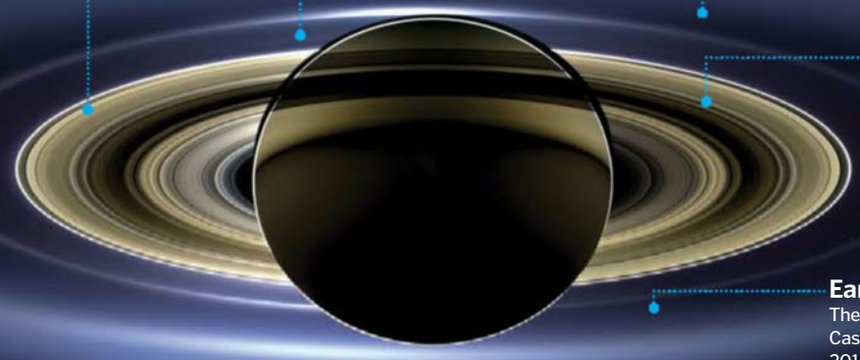
The gas giant Saturn is best known for the disc of material that surrounds it – the 'rings'. These are mostly made of water-ice particles, dust and rock and can be thousands of kilometres wide each. There are gaps between each one, particularly between the seven main rings, but how did these form?

The rings are thought to have been created a few hundred million years ago when one of Saturn's moons was broken up and scattered. Many of the gaps are also known to have been created by moons: the 325-kilometre (202-mile)-wide Encke Gap within the A Ring is kept clear by the orbit of the tiny moonlet Pan.

Orbital resonance, where two celestial bodies exert a regular pattern of gravitational influence, between large moons and the particles in the rings plays a role in the creation of other gaps such as the immensely wide Cassini Division, which is maintained by the moon Mimas.

Spinning right 'round

Saturn's many rings and their gaps explained



Encke Gap
At 325km (202mi) wide, the Encke Gap is relatively small. It's found within Saturn's A Ring and is maintained by the moonlet Pan.

Janus ring
This 5,000km (3,107mi)-wide ring has been created by meteoroid particles that have been ejected off the moons Janus and Epimetheus.

Mimas
The 396km (246mi)-wide moon of Saturn is responsible is responsible for clearing the biggest gap in the rings, the Cassini Division, via orbital resonance.

Cassini Division
Saturn's rings' biggest gap is a huge 4,700km (2,920mi) wide and can easily be seen from Earth using an everyday telescope.

E Ring
The second-outermost ring of Saturn is made of microscopic particles and is extremely diffuse.

Earth
The Saturn-orbiting spacecraft Cassini took this photo in July 2013 and in it, the Earth-Moon system can just be made out, as a single pinpoint of light.

What is space weather?

There's no atmosphere in space, but it still has weather

Just because we have an atmosphere here on Earth, it doesn't mean we have a monopoly on weather. Outer space has weather of sorts too, and it's driven by the same source – the Sun. When we refer to space weather, we're generally talking about what's happening on the Sun and what the solar wind is doing. At key points during its 11-year solar cycle, the Sun releases billions of tons of solar material in what is called a coronal mass ejection (CME), which can cause huge magnetic storms around the Earth. This can make for an impressive northern and southern lights displays known as auroras.

© NASA

"We came up with this idea because kids generally have no concept of just how far away stars and galaxies are"

Interstellar travel guide

How long would it take to journey to the most awesome places in the galaxy?

You might think it takes ages to walk to the shops and back, but what if you had to walk to the Moon, Jupiter or even Andromeda, over 24 quintillion kilometres (14.9 quintillion miles) away? Jenny Shipway and the team at Winchester Science Centre have decided to work out how long it would take to get to various landmarks in our galaxy. They've worked out various means, ranging from a five-kilometre (three-mile)-per-hour walk to the mind-bogglingly fast NASA spacecraft Helios, which zoomed through space at over 241,402 kilometres (150,000 miles) per hour.

"We came up with this idea because kids generally have no concept of just how far away stars and galaxies are," says Shipway. "They think they're closer than they are due to cartoons and films, so it does blow their minds when the hear the numbers."

The measurements are taken based on either maximum or average speeds of the travelling methods, journeying in a straight line until they reach the destination. Admittedly there is a bit of leeway here as there are many factors to take into consideration, such as orbiting time and landing speeds, but they're as accurate as you can get when you consider the enormous distances involved!

Key

- Human – 5km/h
- Car – 113km/h
- Boeing 747 aeroplane – 907km/h
- X-15 rocket plane – 7,258km/h
- Voyager 1 spacecraft – 61,155km/h

Distance to the Moon
363,104km

Earth's diameter
40,075km

Distance to Mercury
77,342,099km

Earth's Moon

Human	9 years
Car	4 months
Boeing 747	17 days
X-15	50 hours
Voyager 1	6 hours

Around the Earth

Human	49 weeks
Car	15 days
Boeing 747	44 hours
X-15	6 hours
Voyager 1	1 hour

Planet Mercury

Human	1,827 years
Car	78 years
Boeing 747	10 years
X-15	1 year
Voyager 1	2 months

Andromeda galaxy

Human	514 trillion years
Car	22 trillion years
Boeing 747	3 trillion years
X-15	342 billion years
Voyager 1	41 billion years

Proxima Centauri

Human	948 million years
Car	41 million years
Boeing 747	5 million years
X-15	631,000 years
Voyager 1	75,000 years

Distance to Proxima Centauri
40,141,022,001,200km

Distance to Andromeda
21,759,215,320,000,000,000km

400,171km

FURTHEST DISTANCE FROM EARTH

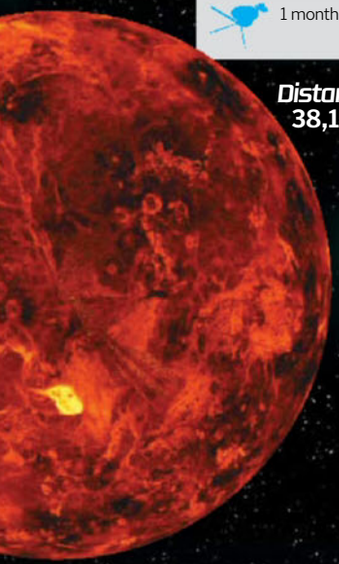
James Lovell, Fred Haise and John Swigert travelled to the far side of the Moon in Apollo 13 on 15 April 1970. No human has ever been farther away from Earth.

DID YOU KNOW? *705 people are in the running to start a colony on Mars from 2024, thanks to Dutch company Mars One*

Planet Venus

- 901 years
- 39 years
- 5 years
- 31 weeks
- 1 month

Distance to Venus
38,147,457km



Planet Mars

- 1,283 years
- 55 years
- 7 years
- 1 year
- 1 month

Distance to Mars
54,304,027km

Distance to Jupiter
588,368,427km

Planet Jupiter

- 14,000 years
- 596 years
- 74 years
- 9 years
- 1 year

Planet Uranus

- 61,000 years
- 3,000 years
- 327 years
- 41 years
- 5 years

Distance to Uranus
2,600,459,792km

Distance to Pluto
4,290,915,734km

Dwarf planet Pluto

- 101,000 years
- 4,000 years
- 540 years
- 67 years
- 8 years

Distance to Saturn
1,269,038,740km

Distance to Neptune
4,305,875,521km

Planet Neptune

- 102,000 years
- 4,000 years
- 542 years
- 68 years
- 8 years

Planet Saturn

- 30,000 years
- 1,285 years
- 160 years
- 20 years
- 2 years

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He has been writing about science and technology since before the web was invented. His sci-fi novel *A Jar of Wasps* is out now.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Alexandra Cheung

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from the University of Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

Will warp bubbles ever become a reality?

William Grant

A warp bubble is a theoretical structure that's part of the Alcubierre drive. This mathematical model of spacetime posits that space could be stretched in a wave, contracting ahead of a spacecraft and stretching behind it. The spacecraft would then time-travel in a bubble of flat space, enabling it to quickly reach other star systems. It's theoretically possible, and NASA has been researching the concept. But in reality, we don't know how we'd provide enough energy to power the warp drive – and that's just one issue to be tackled. So the answer will have to be "perhaps." **SF**

Warp bubbles are one proposed way of ultra-fast interstellar travel

Why does the sea smell like the sea?

Bruce Farley

The smell of the sea comes from a molecule known as dimethyl sulfide (DMS). This molecule derives from a compound called dimethylsulfoniopropionate (DMSP), which is produced by most marine algae. When algae die, the compound is released into the seawater where bacteria feed on it and convert it into DMS. DMS is easily transferred from the oceans into the atmosphere. Once this process has occurred, the smell we associate with the seaside is created. The cycle continues as the Sun eventually oxidizes the DMS, creating sulphate aerosols that act as condensation nuclei and form clouds. **SB**

With continued continental shift, what will Earth look like in 200 million years?

Alan Bradbury

Over the next 250 million years, scientists predict that our planet's continents will converge and form a new super-continent dubbed 'Pangaea Ultima', echoing the supercontinent Pangaea that existed 250 million years ago. The Earth's crust is a jigsaw of pieces of rock called tectonic plates, slowly shifting due to convection currents in the molten rock beneath. In the future, the African plate will move north, closing up the Mediterranean. Antarctica is predicted to collide with Australia and migrate northwards. The Atlantic Ocean will first widen and then close up, bringing the Americas to merge with the other continents in a single, massive, slightly doughnut-shaped supercontinent. **AC**

What would happen if the Earth stopped spinning?

Ashley Curtis

If Earth just stopped turning, everything around the equator would be thrown sideways. The Earth is spinning at about 1,610 kilometres (1,000 miles) per hour at the equator. If that spin suddenly came to a stop, everything at the equator would keep moving at that speed - including the atmosphere. The ground would be blasted with 1,000-mile-per-hour hurricanes. As well as this, a day would last a year – we'd have six months of night and six months of daylight. Finally, the Earth would no longer bulge out at the equator and look like a slightly flattened ball. Instead, it would form a perfect sphere because there's no rotational velocity to counteract the gravitational pull. Oceans, currently held back from the equator due to the bulge, would flood much of the landmasses on our planet, leaving us with one continent around the middle of Earth. Thankfully, NASA have predicted that the odds of this occurring are practically zero. **SF**

How many words does Koko the gorilla know?

Dennis Corolla

According to her longtime keeper and trainer, Dr Francine Patterson, Koko can understand over 1,000 words of American Sign Language. However, this is a very controversial claim. Conversations with Koko are generally very fragmentary and rely on extensive interpretation by Dr Patterson. Since Koko is rewarded with treats whenever she answers a question or correctly describes an object, it is difficult to say whether Koko actually understands the abstract meaning behind the words. Many researchers have argued that Koko is just trying different gestures to get a treat, and Dr Patterson is bending this into a meaningful conversation. **LV**

FASCINATING FACTS

Follicles curl your hair

The curliness of your hair is down to the shape of your hair follicles. If the follicles are symmetrical, they produce straight hairs with a round shaft, but if they are asymmetrical, the hair shaft is oval, and the hairs tend to curl.

What is sneezing?

Sue Billingsworth

A sneeze is one of the body's many natural defences, designed to remove irritants that could cause harm. When dust and other particles in the air enter the nose, they tickle the inside of it. The brain is subsequently sent a message to remove them, and triggers the sneeze. The expulsion of air comes from the lungs and is involuntary, which is why we have little control over it. However, it involves nerves and muscles, as well as the brain and lungs. Your abdominal muscles and chest muscles assist when the air forcefully exits through the windpipe, throat and nasal passages. **SB**

Why does your injured leg swell up? Find out on page 82

BRAIN DUMP

Why do creepy crawlies come out when it's raining?

John Bow

Earthworms crawl out onto the pavement because their burrows become waterlogged. Although worms can breathe underwater by absorbing oxygen through their skin, water holds much less dissolved oxygen than air and worms quickly use up all the available oxygen in their narrow tunnels. Flying insects and small insects, like ants, will normally shelter under leaves and stones during a rain shower because it's no joke to be hit by a raindrop when you are that small. As soon as the rain stops they all come out again at once, to carry on foraging and make up for lost time. **LV**

Why can't I roll my tongue? Is it really genetic?

Connor Burns

The ability to roll your tongue into a sideways c-shape is one that is often thought of as being a simple genetic trait inherited from your parents, but in fact it is slightly more complex. The best way to see if a trait is genetic is to study identical twins, who share the same genetic material. Twin studies revealed that identical twins are more likely to share tongue-rolling abilities than nonidentical twins, demonstrating that there is a genetic component to the trait. However, many pairs had one twin who could roll their tongue and one twin who could not, showing that some of it must be down to environmental factors. Studies on Japanese school children in the 1950s showed that some children are unable to roll their tongues when they are young, but as they grow older they are able to learn the trait, clearly demonstrating that there is more than just genetics at work. **LM**

FASCINATING FACTS

Your singing sounds better in the shower

Bathrooms typically have hard tiled surfaces that reflect sound waves well. In the enclosed space, your voice echoes back and forth, making it seem louder and fuller.

Distilled water is purer

Distilling water involves boiling it and then condensing the steam back to water in a different container. This leaves behind any dissolved minerals and salts, so the distilled water is purer.

Why do injuries cause swelling?

Frank Kirkall

Swelling is one of the five signs of inflammation and often occurs in combination with redness, heat, pain and loss of function. When part of your body is injured, chemical mediators like bradykinin and histamine are released, causing the small blood vessels in the area to expand. As the blood vessels widen they also become leaky, allowing the straw-coloured blood plasma to move out into the tissue. The fluid carries with it more chemicals that aid with the healing process and assist with the function of the immune system. As the tissue starts to heal, the fluid is removed by the lymphatic system and later returned back to the bloodstream. **LM**

Why does my dog sometimes like to eat grass?

Isabelle Johnson

There are a couple of reasons why dogs like to chow down on a patch of grass. One possibility is that they have an upset stomach and eating grass can cause them to vomit the substance that disagreed with them. This is because the blades of grass irritate the throat and stomach lining. However, if the dog is chewing on grass rather than gulping it down, then it could be because they enjoy it or because their body is craving the nutrients grass can offer. It's fairly common for canines to graze now and again and isn't anything to worry about. **AC**

What determines which way 'up' planet Earth is?

Rory Wilkinson

There is no up or down in space; those directions are human constructs. But it's common for us to picture the Earth with the North Pole 'up', or at the top, and the South Pole 'down', or at the bottom. That's how the Earth is generally depicted in maps and models. The reasons why are unclear, because maps made in different regions of the world throughout history have had all kinds of orientations. European maps traditionally had east 'up', while Arab-made maps had the south on top. One theory for the current format is that it's because the Hellenic cartographer Ptolemy made his maps that way, and the most dominant cartographers followed suit. **SF**

Is there really a cure for hiccups?

Andy Dean

Hiccups are caused by irritation of the phrenic nerve, leading to involuntary contractions of the diaphragm. Most cases resolve on their own within a few minutes, but there are lots of at-home remedies that can be tried. The phrenic nerve is responsible for controlling your breathing, and responds to changes in carbon dioxide in your blood, so the aim is to temporarily increase the amount of CO_2 in your system.

Recommended methods include holding your breath, drinking water upside down, breathing evenly into a paper bag, and compressing your chest by leaning forward, or by raising your knees. Hiccups that last more than 48 hours are known as 'intractable hiccups', and the NHS in the UK offers several drug-treatment options, including sedatives, antispasmodics and anticonvulsants. **LM**

Why are paper cuts so painful? Find out on page 84

BRAIN DUMP

What was the worst traffic jam ever?

Faisal Sharma

It depends if you mean the worst in terms of length or duration! The longest-lasting traffic jam occurred on the China National Highway 110 and Beijing-Tibet Expressway in August 2010. Reaching 100 kilometres (62 miles) in length, it lasted 12 days, with some drivers being stuck for five days! With tens of thousands of vehicles on the road, drivers moved approximately one kilometre (0.6 miles) a day.

The longest-stretching traffic jam is believed to have been in Sao Paulo, Brazil, in November 2013. The result of a holiday weekend, jams stretched over 309 kilometres (192 miles) across the city. Drivers in Sao Paulo have been known to read, shave, apply make-up and even watch films during jams. **SB**

FASCINATING FACTS

Seashells do sound like the ocean

The sound you hear when you cup your ear against a seashell is actually noise from around you. The shell captures the noise, which resonates inside it. The sound of the air is similar to that of the ocean moving.

Fibres cause paper-cut agony

Paper cuts are painful because the chemicals and compressed wood fibres deposit particles in the skin over a small area. Paper doesn't cut cleanly, it is blunt and has microscopic jagged edges like a saw. Paper cuts don't bleed much so nerve receptors are left open to the air, making the pain linger.

How do hot-air balloons work?

William Tucker

A hot-air balloon consists of the envelope (the balloon), the burner and the basket. Hot air is lighter than cool air and has less mass per unit of volume, which is why warmer air rises in cooler air. The burner is therefore positioned under the open envelope for the pilot to reheat air.

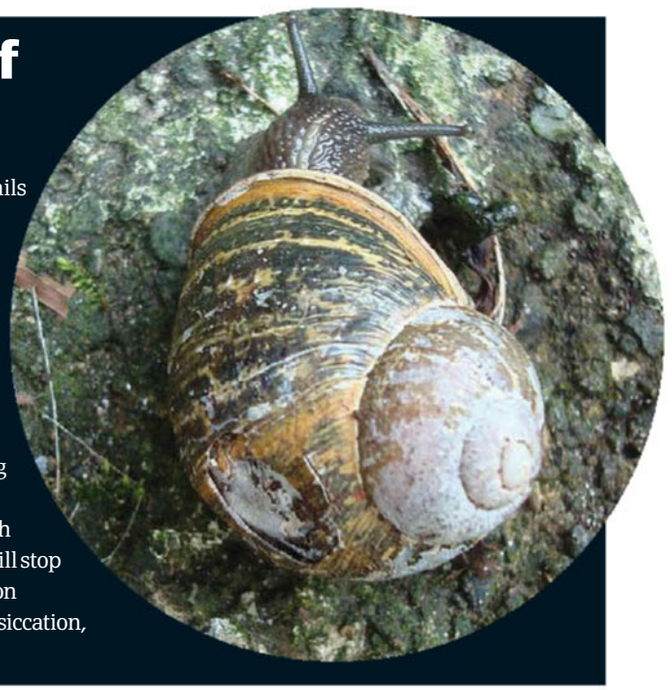
Propane is stored in compressed liquid form in cylinders in the basket. When the propane valve is opened, propane travels through a hose to a heating coil. When the burner is fired, the liquid flows out and is ignited by a pilot light. The flame heats metal in the surrounding tubing, which heats the flowing propane, turning it into a gas that fills the balloon.

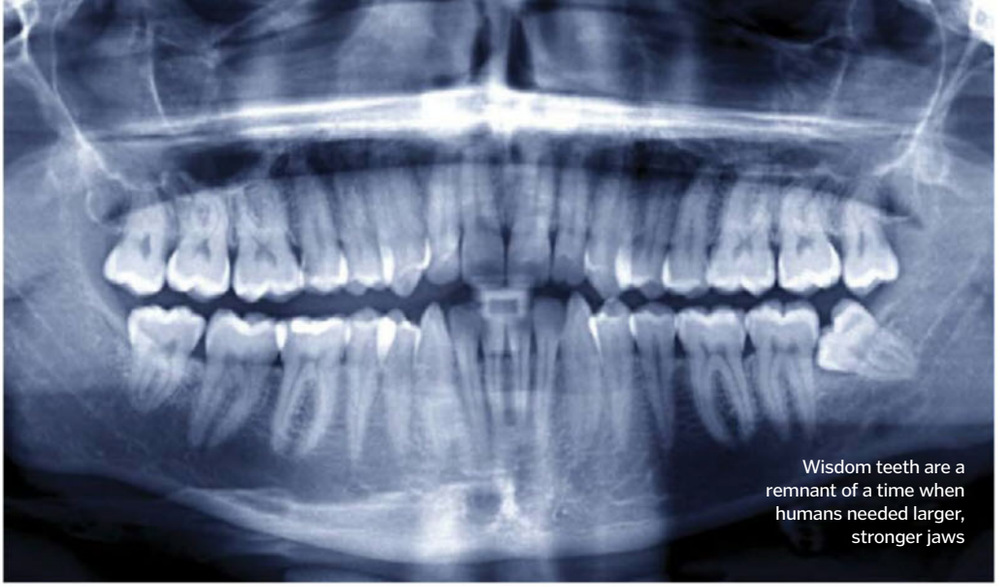
To move horizontally, the vertical position is altered because wind blows in different directions at different altitudes. To move downward, a cord is pulled that opens a valve at the top of the balloon to release the hot air. The cooling of air inside the envelope causes the balloon to descend. **SF**

Can a snail survive if its shell is broken?

Benjamin Bright

Yes, provided that the damage isn't too severe. Snails keep a store of calcium in their bodies, in the form of dissolved salts, that they can mobilise for repair jobs. Special cells, called amoebocytes, will congregate around the crack and form a living elastoplast to hold the broken edges together. Over the course of a week or two, these cells are infused with calcium and gradually harden. In the case of more drastic repairs, the snail may actually borrow calcium from the rest of the shell by slightly thinning the walls from inside, to provide enough building material. While a snail is repairing its shell, it is much more vulnerable to predators and drying out, so it will stop eating and hide away. The snail's survival depends on whether it can repair the damage before it dies of desiccation, hunger or infection. **LV**





Wisdom teeth are a remnant of a time when humans needed larger, stronger jaws

Why are wisdom teeth so painful?

Jacqueline Compton

As humans have evolved, our jaws have become much smaller, leaving little space for our wisdom teeth, which often causes pain as they push against existing teeth. Prehistoric humans had a much larger, prominent jaw and chomped down on a tough diet containing roots and raw meat. Long before the days of dentistry, a third set of molars would have come in handy to replace teeth that had been lost or worn down. Today, our smaller jaws mean that when wisdom teeth emerge, typically between the ages of 17 and 25, they can cause a raft of painful problems. They often grow in sideways and are impacted or blocked by other teeth. The teeth are also prone to infection as food gets trapped under the gums around partially erupted teeth. Modern diets mean we have little need for wisdom teeth any more, and about a quarter of people are missing at least one. **AC**

What is a bruise?

Leanne Horton

Bruising happens when you break the blood vessels below the surface of your skin, allowing blood to leak out into the surrounding tissue, causing swelling and pain. The amazing array of colours produced in a bruise is down to the oxygen-transporting protein haemoglobin, present in red blood cells. To begin with, when the bruise is fresh, the haemoglobin is bound to oxygen and is bright red, but as the oxygen is removed by the tissue, the colour changes to blue-purple. As the bruise begins to heal, the haemoglobin is broken down, first to biliverdin (green), then to bilirubin (yellow), and then to hemosiderin (golden brown), before it is finally removed from the tissue. **LM**

How is skimmed milk made?

Sharon Bristow

The basic system for making skimmed milk involves placing the milk in a centrifuge, a huge machine that contains a stack of discs with holes that align vertically. The machine spins the milk at high speeds, and the denser butterfat moves upward and inward while the skimmed milk moves out and down. Some of the skimmed milk may be processed into non-fat milk solids and added to fluid milk to raise its protein and calcium content. In addition, some skimmed milk – depending on the laws governing milk production in your area – may contain additives such as synthetic vitamins. **SF**

Why do ice cubes crack in your drink?

Emma Quentin

Ice cubes crack due to the difference in how quickly their inner and outer layers warm up and expand. Straight out of the freezer, an ice cube's temperature is around -20 degrees Celsius (-4 degrees Fahrenheit). When it is dropped into a drink at room temperature, the outer layer of ice heats up very rapidly, expanding as it warms up. However, the ice on the inside warms much more slowly and therefore its size doesn't change. The stress caused by the outer layer expanding whilst the core stays the same size causes the ice to crack, producing that characteristic popping noise. **AC**

New Brain Dump is here!

Don't miss issue 18 of **Brain Dump**, the digital sister magazine to **How It Works**, which landed on the digital newsstand on 1 November. Inside, you'll find the answers to life's most intriguing questions, along with beautiful imagery, beamed straight to your smart device. This issue explains why alcohol causes us to lose our inhibitions, what happens when we burn ourselves and how dry cleaning works. You'll also discover fun facts about insects, the Sun and more. Download **Brain Dump** on the first of every month from iTunes or Google Play. If you have a burning question that you want answered, then get in touch via **www.facebook.com/BraindumpMag** or Twitter **@BrainDumpMag**.

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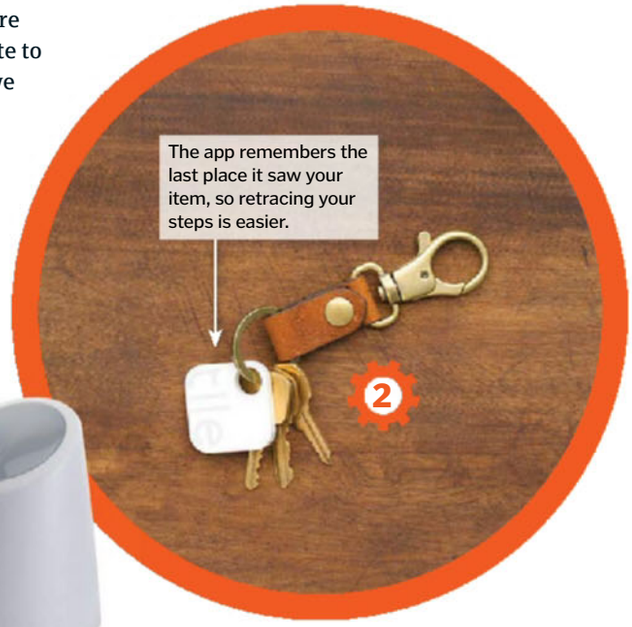
Gadgets you never knew you needed

We test some inventions that are surprisingly useful and make daily life just that little bit easier

Checklist
- ✔ Key tracker
- ✔ Smart switch
- ✔ Signal amplifier
- ✔ Digital highlighter

Technology is brilliant in the way it is capable of solving problems we didn't know we had. The greatest minds in the world beaver away to create solutions to life's little difficulties before we even realise they're difficult. So here is **How It Works**' tribute to those minds as we review the gadgets we never knew we needed.



1 Remote control

WeMo switch
£39.99 / $49.99
www.belkin.com
In a bid to make your home smarter, this device enables you to control your electronic devices from anywhere. The WeMo switch works with Android and iOS to provide wireless control of items like TVs and heaters, so your house can be ready to greet you when you return from work.
Verdict: ✪✪✪✪✪

2 The tracker

Tile
£N/A / $20
www.thetileapp.com
Attach this tiny device to your keys, wallet or anything else you regularly lose and the Tile app will work in harmony with it to help you locate it. It has limited range and you have to be in line with your target, but really handy when searching for your dropped keys.
Verdict: ✪✪✪✪✪

3 Bullet fast

Bullet titanium
£95.57 / $115
www.linitx.com / www.streakwave.com
Radio signals can fluctuate a lot, especially in bad weather. The Bullet Titanium rectifies the situation by using its revolutionary airMAX technology to receive long-distance radio waves with higher reliability and less sound interference. Plug it into an antenna to strengthen your signal.
Verdict: ✪✪✪✪✪

4 Next-gen highlighter

C-Pen 3.5
£114.99 / $199.95
www.scanningpenshop.com / www.amazon.com
This sleek gadget is designed to make the process of using highlighted text much simpler. Just run the pen over printed text and it'll transfer the data straight to your computer or smartphone, so you can get working straight away. Bluetooth technology enables scanning up to nine metres (30 feet) away from your computer or mobile.
Verdict: ✪✪✪✪✪

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Wi-Fi boosters

We round up the products that will get your signal all over the home

Speedy
The Powerline transmits data at 1,200Mbps, which is more than enough for streaming HD films.

How It Works Editor's Choice Award

1 Devolo dLAN 1200 Plus

Price: £137.99 / $N/A
Get it from: www.amazon.co.uk

If the router is in the downstairs front room and your bedroom is the upstairs back room, there's a fair chance your Wi-Fi connection isn't quite as speedy as it could be. This is where the Powerline steps in. All you need to do is plug it into a socket wherever you need a stronger signal, connect your device via network cable to the socket and your connection will be as quick as it is downstairs.

You can hook it up to your computer, smart TV or games console for a faster, more reliable internet connection. This starter kit comes with two adaptors so you can use it in two rooms at once. The set-up is instant, so there's no messing about with installation CDs, which is a great time-saving feature.

The product itself looks as attractive as an adaptor can and has the bonus feature of coming with a plug socket of its own, so you don't lose a socket by plugging it in.

We really like this product as it works perfectly, is easy to use and boosts your signal without losing that precious socket.

Verdict: ✪✪✪✪✪

ON THE HORIZON

What else can we web surfers look forward to?

60GHz transmitters

Plug your device into the transmitter and a projector into the receiver and stream video at a whopping 60GHz. The tech is here already but needs refining.

Next-generation Wi-Fi hotspots

Entering passwords and usernames to access a Wi-Fi hotspot could soon be a thing of the past with Passpoint, a secure certificate that connects you automatically.

2 ZyXEL WRE2205 Wireless Extender

Price: £19.99 / $84.99
Get it from: www.dabs.com / www.amazon.com

The WRE2205 is small and unobtrusive, but the effect it has is anything but. It is capable of massively extending the wireless coverage around your home and has a number of handy extra features on the adaptor itself. An LED on the front shows you how much signal the adaptor is receiving from its spot in the building so you know where it is needed the most. This is really handy for those who are unsure of where in their home their signal is strongest and is an extremely useful feature.

It looks neat and slick, but will use up a power socket, so you will probably need to use an extension cable with it if you've got multiple devices.

It does take a little longer than the others to set up as you need to install the device with a CD, but it's easy enough to follow.

For the price, this extender is a real bargain and works well, but we would have appreciated an extra power socket on the adaptor, but all in all this is a pretty good and cheap way to boost your home's Wi-Fi signal.

Verdict:

Power down
You can reduce the power output to stop it interfering with your neighbour's Wi-Fi.

Add an app
You can download a free app that controls security features and browsing restrictions.

3 Devolo dLAN 500 AV Wireless+

Price: £89.99 / $N/A
Get it from: www.amazon.co.uk

In our heavily internet-reliant world, there is rarely just one Wi-Fi-enabled device in need of a boost. Whether it's a smartphone, laptop, games console or smart TV, there are bound to be times when you'll need to boost more than one device, so the 500 AV Wireless+ is ideal.

All you need to do is plug one of the adaptors into your router and the other into a socket in whatever room you need a stronger signal and you'll experience an improved Wi-Fi signal as it transmits up to 500Mbps over Powerline and up to 1,000Mbps when using the Ethernet cable, which should be plenty for most tasks.

The three LAN ports are a useful extra if you've got a number of devices you want to hook up, but the signal boost you get from the device should be more than enough in most cases. If you've been plagued by slow and unreliable internet connections in the farthest reaches of your home, we can't recommend the 500 AV Wireless+ highly enough because it does exactly what it says it will do and does it with no fuss or hassle.

Verdict:

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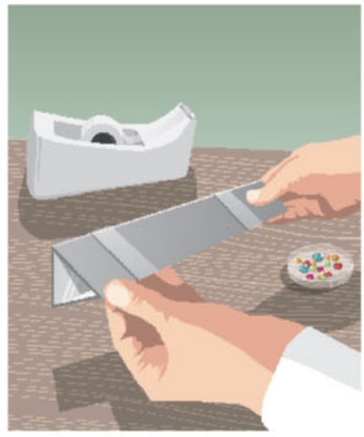
Make a kaleidoscope

Create an amazing world of colour and light from simple products

1 Preparation

To make a kaleidoscope, you'll need a standard kitchen roll tube, mirrored card (or foil glued onto card) at least 7.5x21cm (3x8in) and small, transparent objects like sequins or sweets wrappers. The more colourful the better! You'll also need two plastic discs, which can be cut out from empty food containers. The circles should measure 5cm (2in) across. One disc should be transparent and the other should be frosted.

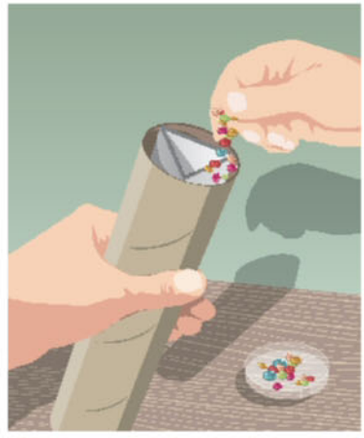


2 Create your mirror

To create a mirrored prism, cut the shiny card into three equal strips, each one 2.5m (1in) wide and 21cm (8in) long. Then line up the long edges of one strip with the long edges of the other two pieces and sellotape them together. Push the two free edges together so they form a triangular prism with the shiny sides facing inward. These will reflect against each other and create the amazing patterns.

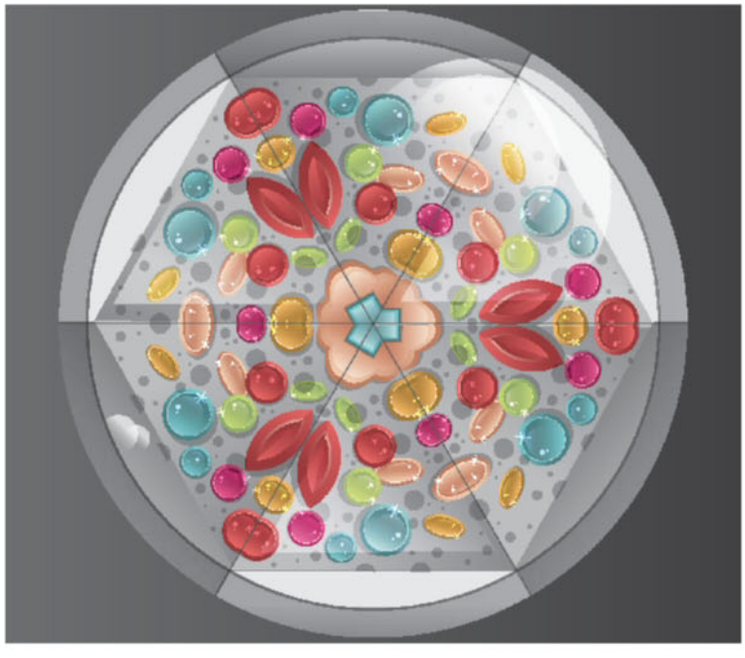
3 Make it snug

Push the triangular prism inside the kitchen roll tube. It should fit snugly inside, but the mirrors should be slightly smaller than the length of the tube. Position the prism so it sits level with one end of the kitchen roll and then turn it over. Take one of your transparent plastic discs and put it on top of the prism. Once you're happy with its position, tape it into place inside the kitchen roll tube.



4 Finish your kaleidoscope

Now pour in the colourful see-through items. The objects need some room to move around, so make sure you don't include too many. Then take the frosted plastic disc, place it onto the end and secure this with tape. If you don't have frosted plastic, just glue some grease-proof baking paper onto one side. Then turn the tube over and tape a disc of cardboard with a small hole cut into the centre on this end.



5 The science bit

Hold the viewhole up to your eye and slowly rotate the kaleidoscope to see the incredible images. It works by filtering light through the end of the object chamber and illuminating the colourful items inside. The light then reflects off the mirrors like a bouncing ball, which creates the patterns. By turning the tube, the objects move about and the reflection changes so you don't see the same pattern twice.

In summary...

Creating a kaleidoscope is all about precision. The mirrors need to be exactly the same size as each other to create a perfect equilateral triangle. Make sure the cap is on tightly so you've got a straight-down view and then the world is your psychedelic oyster.

NEXT ISSUE
- Take the perfect portrait
- Blow up a balloon with science

Create a bottle tornado

Make one of the world's most destructive natural forces in your very own kitchen

1 Set it up

For this experiment you'll need a clear plastic water bottle, water, some washing-up liquid and some glitter. The glitter isn't actually essential to the experiment, but it makes the whole thing much more fun! The first step is to fill the bottle until it is around three-quarters full. Any more and the 'tornado' won't have a chance to build up, any less and it won't look nearly as impressive. Remove any labels from the bottle, which needs to be at least 500ml (16.9fl oz).

2 Create your tornado

Pour in a few drops of washing-up liquid and a couple of scoops of glitter. Allow it to settle for a few seconds before screwing the lid on. It needs to be extremely tight as you're going to be turning the bottle upside down and you don't want glittery water all over your shoes. Once you're sure the bottle is watertight, turn it upside down, holding it by its neck. Spin the bottle quickly for around ten seconds and then stop abruptly.

3 Admire your creation

Once you've stopped, look in the middle of the bottle. You should see a mini tornado form inside. The glitter and washing-up liquid will help you see the spinning vortex that has formed inside the bottle. This happens due to centripetal forces. As you rotate the bottle, the water spins around a central axis. Centripetal force is pushing the water that naturally wants to fly out of the bottle inward. This is how tornadoes in real life are formed, using high-speed winds instead of bottle spinning.

In summary...

This fascinating experiment is possible due to centripetal force. Make sure you don't fill the bottle up too much and give it a handful of fast but controlled rotations. If it doesn't work the first time, try again with a few more rotations to get it going.

QUICK QUIZ

Test your mind with ten questions based on this month's content to win an Airfix model of a Boeing 737 airliner.

Answer the questions below and then enter online at **www.howitworksdaily.com**

1. Other than *Countdown*, which TV program does Rachel Riley present?
2. What type of aeroplane carried the first commercial plane passenger?
3. What is the widest gap in Saturn's rings called?
4. Which of the four states of matter is our Sun made of?
5. In what year was the Massachusetts State House completed?
6. What is the name of the specialised cell that produces bone cells?
7. How long is the average grey whale (in metres)?
8. What are the muscles between the ribs called?
9. What are the colour-sensitive proteins in your eye called?
10. How many pixels per inch (ppi) does the iPhone 6 Plus Retina HD screen have?

ISSUE 65 ANSWERS

1. 46 **2.** Sulphur **3.** Delaware **4.** 2001 **5.** Chalcedony **6.** King Clone **7.** 1898 **8.** Three **9.** St Edward's Crown **10.** 80

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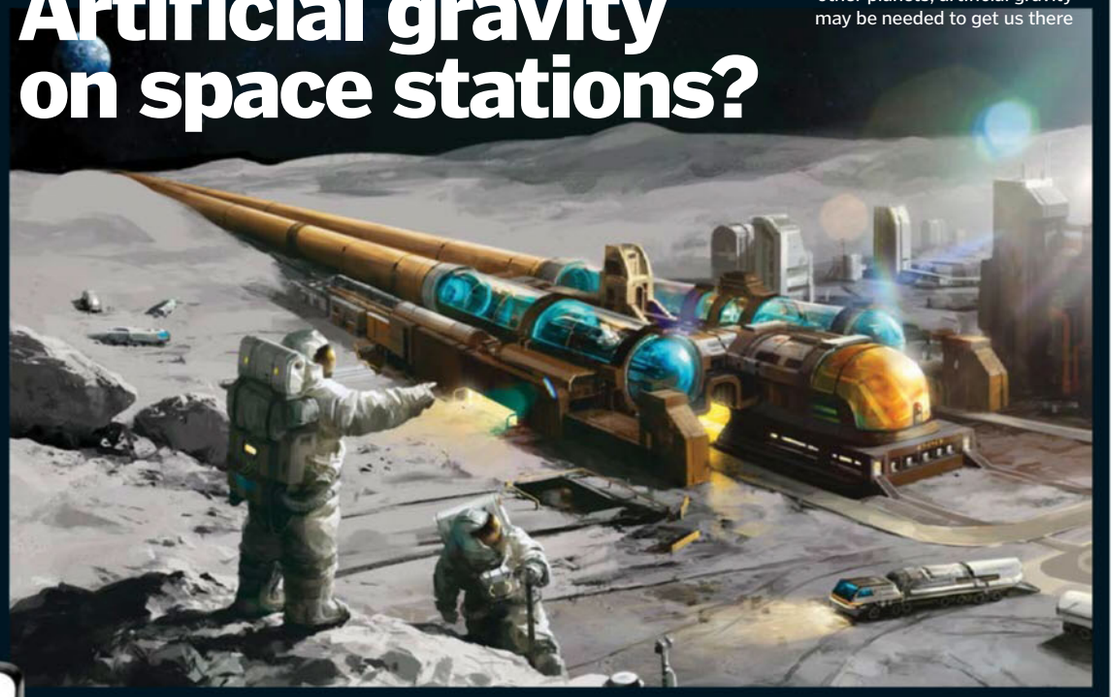
Next issue's letter of the month will win an HDMI Switch from Maplin. Never get your wires in a tangle again with this handy little device that puts all your HDMI ports into one place.

Letter of the Month

Artificial gravity on space stations?



If we ever create colonies on other planets, artificial gravity may be needed to get us there

Dear **HIW**,

I can't begin to thank you about how good this magazine is and I've only started reading it as of the last issue, you guys are doing a great job!

While I was reading issue 64 I saw the article about Ask An Astronaut and it had a section on living in a zero-gravity environment aboard the ISS. At school I was told that a spaceship could create its own gravity by continually rotating through space and would not only lessen the effects of zero gravity on our body but also have no effect on our internal organs, so is this possible or is it the work of fiction?

Films such as *Elysium* and *2001: A Space Odyssey* all show it as a possible concept, because if a spaceship could produce its own artificial gravity, our exploration onto distant planets would be possible. And finally, if artificial gravity is real why has nobody built a spaceship capable of utilising it?

Kind regards

Adam Fazil

We've done some research and found out that, yes, it is possible for a spaceship to create its own gravity. To do this, you have to generate an intense centrifugal force within the ship, which will produce a pulling sensation toward the floor. It will feel a bit strange as the wall will now be the floor and vice-versa, but it will stop all that pesky floating around!

Another idea that has been proposed is the use of high-powered magnets to clamp everything down, although its safety for humans is still unknown. The reason why none of these methods have been used yet is primarily due to expense and a lack of investment in long-distance space travel, but also the fact that a spaceship fitted with artificial gravity would have to be very large to work properly and warrant the expenditure. If we do go to Mars in the future, though, artificial gravity will surely play a part. Until then, *2001: A Space Odyssey* is still the nearest you can get!

Green flashes in the sky

Dear **HIW**,

I hate to be a killjoy and contradict your absolute (twice repeated even, in two separate issues, the last in the letters section for July 2014), certainty that the sky is never ever green.

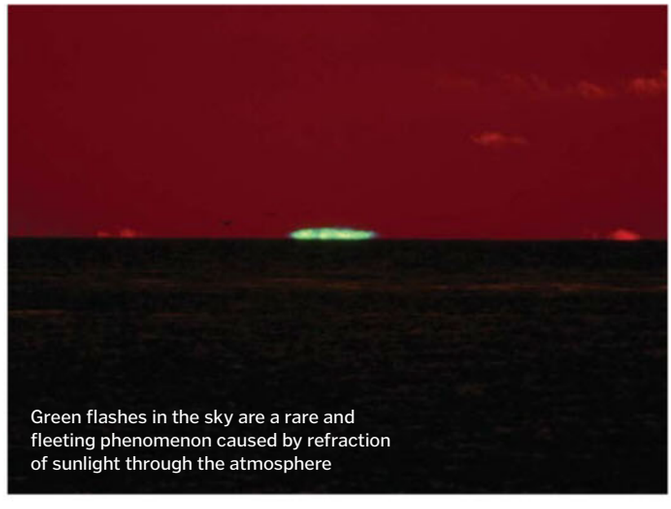
May I point out the green flashes, which occur near or at sunset under given conditions. A significant section of the setting sky turns brilliant green. I've seen this three times in my life and somewhere actually have a photograph [of a green flash].

Kind regards,

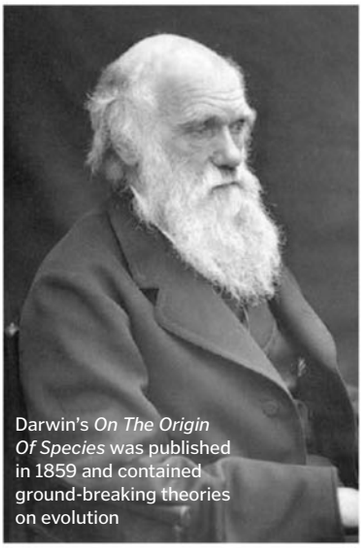
Dave Stasinski

When we answered a reader's question in issue 60, we stated that even though green is between red and blue in the visible light spectrum, it is more often that not, shrouded by the stronger colours. It is usually perceived by our eyes as cyan or turquoise colour rather than green. On rare occasions though, there are green flashes in the sky.

Created when a small portion of the Sun is visible above the horizon, the bright green flashes show the changing of the light spectrum as day turns to night. Usually the different colours of sunlight overlap each other, so we see a range of hues rather than individual wavelengths. On rare instances, the conditions are just right for a single colour to flash as the top of the Sun disappears below the horizon. The green light you saw is the most common example, but flashes of blue or violet also occur. You're very lucky to have seen three!



Green flashes in the sky are a rare and fleeting phenomenon caused by refraction of sunlight through the atmosphere



Darwin's *On The Origin Of Species* was published in 1859 and contained ground-breaking theories on evolution

A question of evolution

■ Dear **HIW**,
How did life spontaneously generate out of nothing? Something can't come from nothing, and if it could we would probably see it happening today. Also, how can red blood cells in dinosaur bones last millions of years?
Zach (11)

Earth itself formed around 4.6 billion years ago. The first life didn't arise until approximately 3.8 billion years ago when single-celled prokaryotic cells like bacteria emerged. This was followed in time by more complex cells and organisms. The reason why life first appeared is still contested. Many believe that as soon as Earth's atmosphere and environment became stable for carbon-based life, RNA and DNA began to form and divide thus creating life and eventually the LUCA (Last Universal Common Ancestor). Others believe it all started when the first molecules developed the ability to metabolise and began to break down the carbon dioxide in the atmosphere and collect energy. From here on out, as Charles Darwin said, natural selection did the rest. As for dinosaur bones, we have an article based on them in our last issue (65). Check it out!

"Actually, all compact objects (white dwarfs, neutron stars and black holes) do distort space-time"

Magnetars, dark matter and the human brain

■ Dear **HIW**,
I have read issue 64 and am a subscriber. I joyfully read each issue from front to back. If magnetars are so powerful, could they distort space and time in such a way that it would enable us to see into another dimension? Also, how much dark matter and energy do they possess? By the way, how long would it be to be able to fully understand the human brain? Thanks and love the issue.
Isaac Blyton

We contacted Professor Phil Charles, who is the head of Physics and Astronomy at the University of Southampton, to answer both of your questions: "Actually, all compact objects (white dwarfs, neutron stars and black holes) do distort space-time, and we have already measured this effect, for example, through the gravitational redshift induced in the light that comes to us from close to the compact object. Dark matter contains about 25 per cent and dark energy contains approximately 70 per cent of the total energy content of the universe."

As for your question on the brain, modern neuroscience is attempting to increase our understanding of the brain as much as possible, but it may be a while yet until we fully understand all of our mind's workings, as it is an incredibly complex organ.

What's happening on... Twitter?

We love to hear from **How It Works**' dedicated followers. Here we pick a few tweets that caught our eye this month...

Amelia Blow @AmeliaBlow
Reading 'Ask An Astronaut' in **@HowItWorksmag** makes me want to be an astronaut even more :)

brenda jarvie @bejar001_bj
@HowItWorksmag #winitwednesday cool and exciting prize x

Local Motors @localmotors
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We are looking forward to reading the Q&A with our Head of Planetarium – Dr Jenny Shipway in next month's **@HowItWorksmag** #WinSciCentre

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@HowItWorksmag if I lived in Stoke, I really wouldn't want an ancient volcano poked about with under me! x

Jason Taylor @Bridge1Sol
Got home to find the latest edition of **How It Works Illustrated** on the doorstep. Kids love it! **@HowItWorksmag** #awesome

HOW IT WORKS

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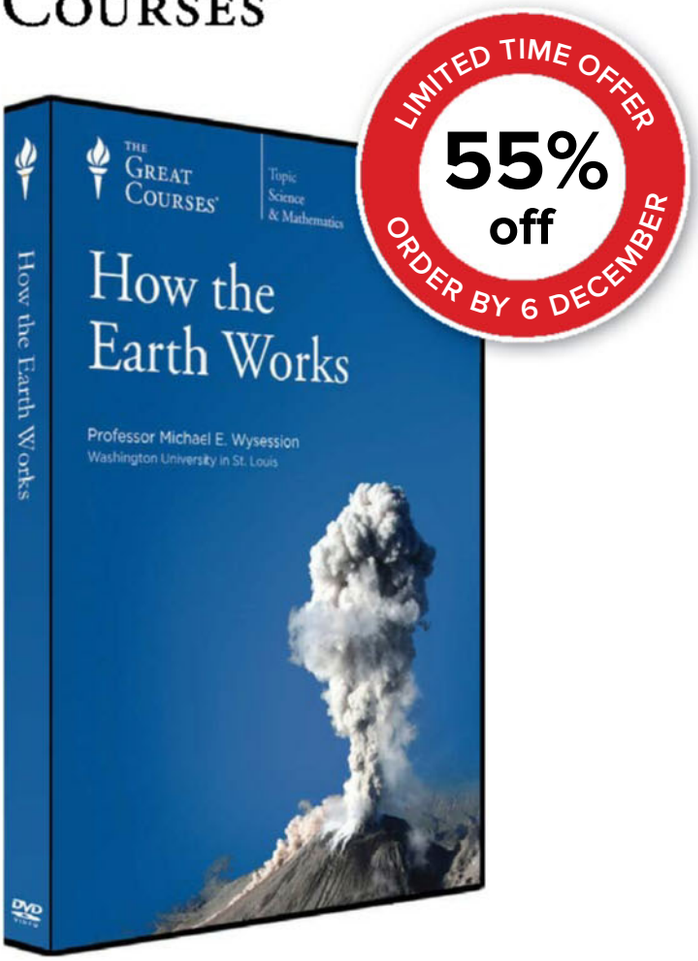

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